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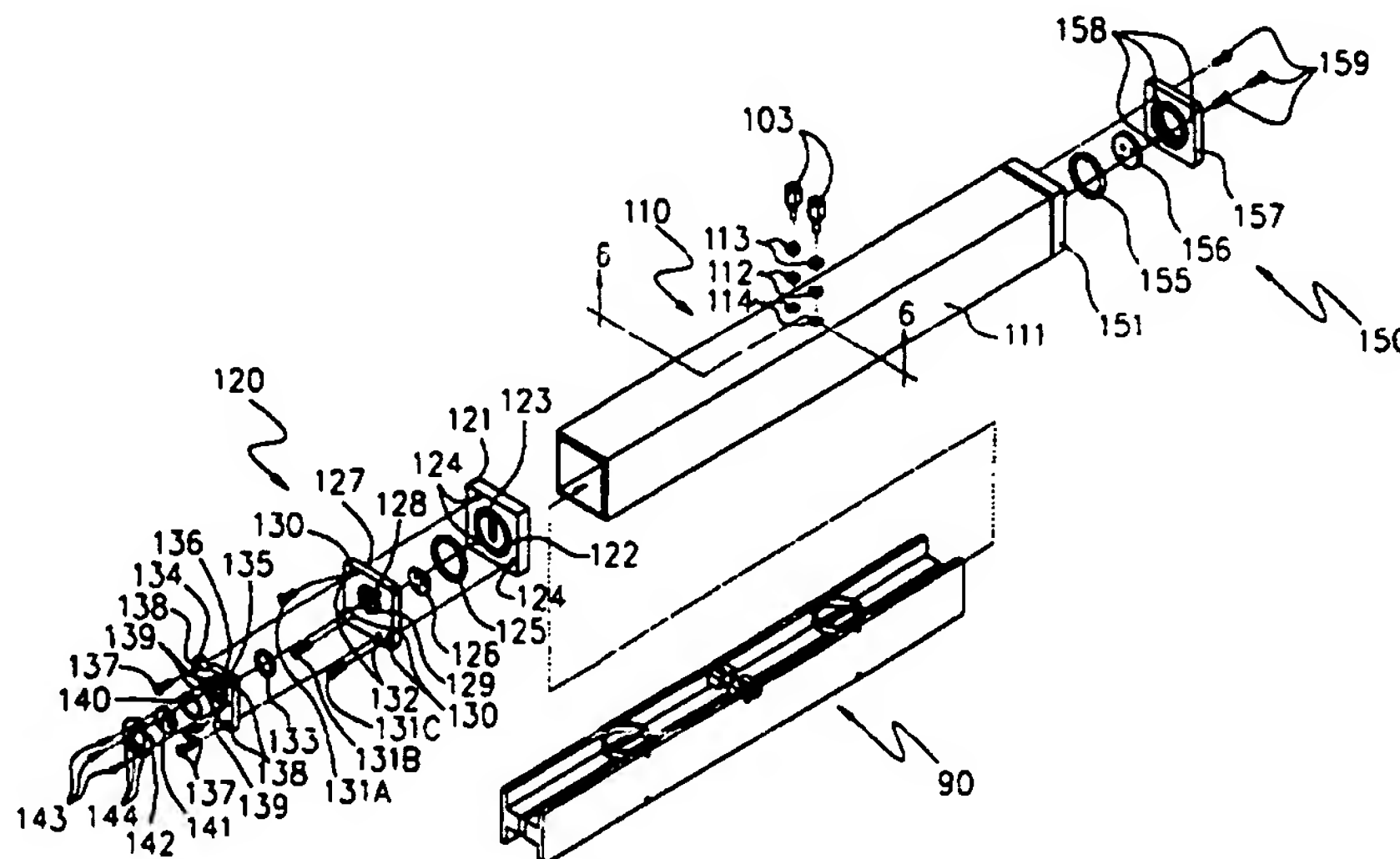
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(54) Title: **FREE-SPACE GAS SLAB LASER**



(57) Abstract

A pair of elongated, parallel electrodes (91, 92) form a rectangular gas discharge area (40) in a tubular housing (111). The minimum spacing (a) between the electrodes is the diameter of the fundamental free-space mode of the stable laser resonator (17). A multi-pass optical configuration (30, 50) uses the full width (b) of the active medium to produce a high power compact laser (10, 200). Deformable support rings (97) are compressed to push the electrodes apart against cylindrical spacers (99) to maintain the electrodes' spatial relationship. The rf feeds (103) are sealingly (112) connected to the electrodes through the housing. Air cooled heatsinks (161, 162, 176, 177) are held tightly while being flexibly mounted to the laser tube reducing torsional distortion, misalignment and instability.

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# FREE-SPACE GAS SLAB LASER

## I. Background of the Invention

### A. Fields of the Invention

The present invention relates generally to coherent light generators of the gas discharge laser variety, and, more particularly, to a gas slab laser configured with an improved electrode structure and a multi-pass, non-waveguide, that is, free-space, resonator with improved heat transfer and cooling apparatus.

### B. Discussion of Background and Prior Art

There has been a considerable investigation into various forms of waveguide and slab CO<sub>2</sub> lasers. Hobart U.S. Patent 5,123,028 ("the '028 patent") at 1:9-3:13 (Citations are to column and line number).

#### 1. In-Line, Non-Slab Gas Lasers

Most non-slab lasers, for example, K. Laakmann U.S. Patent 4,169,251 ("the '251 patent") and P. Laakmann U.S. Patent 4,805,182 ("the '182 patent") require a relatively large length to output power ratio. In a typical well known "in-line" configuration, e.g., the Laakmann '251 patent, a pair of elongated, insulated electrodes are disposed parallel to each other with radio frequency ("RF") excitation applied transverse to the laser light beam formed in the discharge zone between the electrodes and a reflective mirror at each end of the single-pass resonant cavity. In order to achieve a predetermined power intensity, the cavity has to be long to allow sufficient light amplification. Thus, the length to

1 output power ratio is high. This configuration presents a  
2 practical problem in that the length of the laser determines  
3 the length of the outside equipment into which the laser is  
4 installed. Long laser equipment presents many obvious  
5 problems, limiting its use. E.g., the long laser equipment is  
6 not portable, cannot be used on desk tops, and is more  
7 expensive to build.

8 An additional problem with the in-line laser design using  
9 the metal-ceramic combination (Laakmann '251) is the uneven  
10 thermal expansion caused by the different coefficients of  
11 expansion of the metal electrodes and ceramic wall members  
12 which cause serious operational problems, including a  
13 mechanical instability and misalignment resulting from  
14 deformation of the laser tube.

15 While the P. Laakmann '182 configuration improved the K.  
16 Laakmann '251 design by introducing the advantage of similar  
17 materials, i.e., the all metal design, it did not solve the  
18 problems associated with the relative high length to output  
19 power ratio of the in-line design.

20 Accordingly, it is a primary object of the present  
21 invention to provide a compact laser configuration and  
22 resonator design which provides a low length to output power  
23 ratio, thereby enabling flexible design and many additional  
24 laser uses.

25 Accordingly, it is a further object of the present  
26 invention to provide an improved cooling system mounting  
27 structure and heatsink design which eliminates distortion of

1 the laser tube and the resulting mechanical and operational  
2 instability and misalignments.

3 A still further problem with the in-line design of the  
4 prior art, e.g., the Laakmann '251 and '182 patents, is the  
5 "waveguide effect". Reflections of light from the surfaces of  
6 the electrodes and from the walls of the dielectric members,  
7 adjacent the discharge zone due to the close proximity of  
8 those surfaces which form a constrained symmetrical bore in  
9 the discharge zone, cause a non-uniform distribution of the  
10 energy in the beam in the near field making it unacceptable  
11 for a variety of applications. While this problem may be  
12 corrected by using the more uniformly distributed far field  
13 beam or filtering techniques, such solutions are not always  
14 available or practical, and, at the least, add significant  
15 costs. In a compact laser design with limited space between  
16 the laser output optic and the focusing optic such solutions  
17 are not optimal.

18 Accordingly, it is a further object of the present  
19 invention to provide a free-space, in all directions, gas  
20 laser design which provides substantially uniform energy  
21 distribution in both the near and far fields thereby further  
22 reducing the cost and simultaneously enhancing the utility of  
23 the compact laser design.

## 24 2. Slab Waveguide Lasers

25 Slab waveguide lasers have been known for some time. An  
26 early gas slab laser design is shown in Tulip U.S. Patent  
27 4,719,639 ("the Tulip '639 patent"). A more recent design is

1 shown in Hobart U.S. Patent 5,123,028 ("the Hobart '028  
2 patent").

3 The main advantage of slab waveguide lasers is their  
4 ability to generate high power in a short active medium. This  
5 capability derives from the fact that slab waveguide lasers  
6 have a discharge area that is typically rectangular in cross  
7 section enabling the use of the full available width of the  
8 active medium to achieve greater overall output power.

9 However, it is this very use of two different types of  
10 resonators that produces the main disadvantage of slab  
11 waveguide lasers of the prior art, i.e., inherently lower  
12 overall beam quality than the in-line design lasers. P.  
13 Laakmann, "The Market Continues to Grow for Sealed Carbon  
14 Dioxide Lasers", Industrial Laser Review, October, 1993. This  
15 deficiency can only be corrected through the use of complex  
16 and relatively expensive optical systems. The resulting beam  
17 of such a hybrid gas slab laser has different properties in  
18 different directions. In the narrow direction, the electrode  
19 surfaces create a waveguide effect. In the wide direction,  
20 there is no physical restriction, and the beam is formed as in  
21 a free-space laser resonator. The result is greater  
22 divergence of the beam after it leaves the laser along the  
23 waveguide axis (narrow dimension) than along the non-waveguide  
24 axis (wide dimension). Hobart '028, Fig. 19. (corrected for  
25 obvious clerical errors). However, this low beam quality is  
26 partially correctable, but only through the use of complex  
27 optical systems which are relatively expensive. Accordingly,

1 it is an object of the present invention to provide a high  
2 efficiency, high power gas slab laser which uses the free-  
3 space, non-waveguide, stable resonator in both directions  
4 producing a high quality uniform beam and eliminating the need  
5 for complex optics.

6       Folded type gas lasers are also not new. Laakmann '182  
7 Figs. 5-6. Recent gas slab waveguide lasers have also  
8 utilized folded designs to achieve greater power in shorter  
9 lasers. Koop U.S. Patent 5,353,297 ("the '297 patent"). The  
10 Koop '297 patent teaches a hybrid resonator design which is  
11 operating as a stable waveguide in the narrow axis and a  
12 negative branch unstable resonator in the wide axis.  
13 Additionally, Koop adds a pair of mirrors at each end of the  
14 electrodes to create a folded beam path in the wide axis.  
15 Koop, therefore, exemplifies the problems described above.  
16 Accordingly, it is an object of the present invention to  
17 provide a compact, gas slab laser which uses a simple,  
18 inexpensive, multi-pass, optical system with the laser light  
19 beam operating in a non-waveguide mode in all directions in  
20 the resonator discharge cavity.

21       Another problem in gas slab laser design is the  
22 supporting structure for positioning the electrodes within the  
23 laser tube to maintain a predetermined gap between the  
24 electrodes in insulated relation to the walls of the housing  
25 with minimal capacitance and good thermal conductivity. The  
26 electrode gap dimension is critical to optimal laser  
27 operation. The spacing between the electrodes and housing is

1 critical to properly balance maximum heat transfer (small  
2 spacing desired) and maximum inherent capacitance of the  
3 structure for high quality RF matching (large spacing  
4 desired). Accordingly, it is an object of the present  
5 invention to provide an improved electrode support structure  
6 and housing wall spacing configuration which optimizes the  
7 operating parameters of the laser.

8 II. Summary of the Invention

9 Set forth below is a brief summary of the invention in  
10 order to achieve the forgoing and other benefits and  
11 advantages in accordance with the purposes of the present  
12 invention as embodied and broadly described herein.

13 One aspect of the invention is a gas slab laser having a  
14 gas containment structure, a pair of parallel, electrically  
15 insulated electrodes mounted in the gas containment structure  
16 and forming a gas discharge area having a rectangular cross  
17 section, a laser gas mixture sealed in the gas containment  
18 structure, an RF feed terminal coupled to each electrode and  
19 adapted to couple to a source of RF-excitation, and an  
20 arrangement of reflective optical elements mounted to  
21 opposite ends of the gas containment structure adapted to form  
22 a laser resonator, the minimum distance between the electrodes  
23 being not less than the maximum cross-sectional size of a  
24 fundamental mode of a stable laser resonator beam operable  
25 substantially in free-space in any direction within the  
26 rectangular cross section.

1           In a further feature of this aspect of the invention each  
2   electrode is an elongated, T-shaped electrode made of anodized  
3   aluminum having an aluminum oxide coating in the range of  
4   about .025-.01mm.

5           A further feature of this aspect of the invention  
6   includes the gas containment structure having an aperture  
7   through which the RF terminal extends with a clearance fit,  
8   and an o-ring compressed between the electrode, the RF  
9   terminal and the gas containment structure to seal the gas  
10   containment structure without applying any substantial force  
11   to the electrode.

12          Further features of this aspect of the invention include  
13   at least one optical element with a concave reflective  
14   surface, an output coupler which is partially reflective, and  
15   a multi-pass laser resonator having at least two optical  
16   elements, one of which is a partially reflective optical  
17   element with a coefficient of reflection which is a function  
18   of the number of passes in the multi-pass resonator.

19          Still another feature of this aspect of the invention is  
20   an arrangement of optical elements which includes an optical  
21   assembly at each end of the gas containment structure wherein  
22   each optical assembly further includes an end plate closing  
23   the end of the gas containment structure having an aperture  
24   therein, a first support plate secured to the end plate at a  
25   pivot point, at least one reflective mirror affixed to the  
26   first support plate and aligned with the aperture in the end  
27   plate to receive and reflect light from the discharge area, an

1 o-ring compressed between the end plate and the first support  
2 plate sealing the gas containment structure, the first support  
3 plate being adjustable about a vertical axis by a screw in a  
4 horizontal plane with the pivot point and about a horizontal  
5 axis by a screw in a vertical plane with the pivot point.

6 In still another feature of this aspect of the invention  
7 one of the optical assemblies is at the front end of the gas  
8 containment structure and includes a second support plate  
9 having an aperture therein and secured to the first support  
10 plate at a pivot point, a second reflective mirror affixed to  
11 the second support plate and aligned with the aperture  
12 therein to receive and reflect light from the discharge area  
13 and to transmit light outside the gas containment structure,  
14 an o-ring compressed between the first support plate and the  
15 second support plate sealing the gas containment structure,  
16 the second support plate being adjustable about a vertical  
17 axis by a screw in a horizontal plane with the pivot point and  
18 about a horizontal axis by a screw in a vertical plane with  
19 the pivot point.

20 A second aspect of the invention is a plurality of rigid,  
21 deformable support members mounted between the electrodes for  
22 maintaining the spatial relationship of the electrodes.

23 A further feature of this aspect of the invention is each  
24 deformable support member may be made of anodized aluminum and  
25 includes a ring, and a screw engaging opposite sides of the  
26 ring for compressing the opposite sides in one direction to  
27 spread the electrodes in another direction until the

1 electrodes are firmly secured within the containment  
2 structure.

3 A further feature of this aspect of the invention is a  
4 plurality of short cylindrical spacers with a small cross-  
5 section maintaining the electrodes in spaced relation to the  
6 inner walls of the gas containment structure while providing  
7 minimal capacitance.

8 A third aspect of the invention includes each electrode  
9 having a large surface portion supported in close proximity to  
10 the inner wall of the gas containment structure to facilitate  
11 heat transfer, a pair of elongated heatsinks contiguous those  
12 outer surfaces of the gas containment structure which are  
13 adjacent the large surface portions of the electrodes inside  
14 the gas containment structure, a pair of cover plates each of  
15 which is secured to each heatsink, and a plurality of flexible  
16 spacers between the cover plates and the gas containment  
17 structure, the heatsinks and cover plates forming a flexible  
18 enclosure surrounding the gas containment structure allowing  
19 uniform heat transfer while eliminating thermal expansion  
20 forces tending to deform the gas containment structure.

21 A further feature of this aspect of the invention  
22 includes the heatsinks having a plurality of threaded holes,  
23 and the cover plates having a plurality of countersunk holes  
24 offset slightly inwardly from the threaded holes, whereby when  
25 the cover plates are secured to the heatsinks by screws  
26 through the countersunk holes, the heatsinks are drawn snugly  
27 against the gas containment structure surfaces while the o-

1 rings are compressed and position the cover plates in close  
2 spaced relation to the gas containment structure.

3 A fourth aspect of the invention is an assembly of  
4 electronic components mounted on the flexible enclosure and  
5 coupled to the RF terminals, and a fan assembly covering each  
6 heatsink forming a plurality of air channels for removing heat  
7 from the gas containment structure and electronic components

8 A further feature of this aspect of the invention  
9 includes a hollow tube disposed within each heatsink for  
10 passing coolant liquid therethrough for removing heat from the  
11 gas containment structure.

12 Other aspects of the present invention will be understood  
13 by reading the detailed description of the invention below.

14 A gas laser designed as a free-space slab laser according  
15 to the present invention has the following advantages:

16 1. A compact construction with a small length to  
17 power ratio enabling portability of the laser and  
18 substantially enhanced utility;

19 2. A flexibly mounted heatsink assembly which  
20 eliminates torsional deformation and provides improved  
21 mechanical and operation stability.

22 3. A favorable geometric configuration which  
23 enables a rugged, very high density final package thereby  
24 substantially reducing the overall size and cost;

25 4. In a multi-pass configuration, the near field  
26 distribution of energy in the laser beam is substantially

1 uniform, allowing laser beam focusing in the near proximity to  
2 the laser output coupler;

3 5. The ability to generate in a multi-pass  
4 configuration a symmetrical Gaussian beam with equal  
5 divergence in all directions within the beam cross section  
6 thereby facilitating the use of a simple beam delivery system.

7 6. An efficient thermal conductivity and heat  
8 transfer design which provides improved operational stability.

9 III. Brief Description of the Drawings

10 Fig. 1 is a schematic representation of the spatial  
11 relationship between the diameter of the Gaussian beam of the  
12 fundamental mode and the electrodes inside of the free-space  
13 slab laser of the present invention configured as a stable  
14 resonator in both directions.

15 Fig. 2 is a side (as seen in Fig. 6) schematic  
16 representation of the beam trajectory inside a stable, free-  
17 space, two-pass resonator of the present invention.

18 Fig. 3 is a side (as seen in Fig. 6) schematic  
19 representation of the beam trajectory inside a stable, free-  
20 space, five-pass resonator of the present invention.

21 Fig. 4 is an exploded perspective view of the electrodes,  
22 supports and spacers sub-assembly for the free-space, slab  
23 laser configuration of the present invention.

24 Fig. 5 is an exploded perspective view of the laser tube  
25 sub-assembly of the present invention.

26 Fig. 6 is a cross sectional view taken along the lines 6-  
27 6 of Fig. 5.

1        Fig. 7 an exploded perspective view of the laser tube and  
2        heatsinks sub-assembly of the present invention.

3        Fig. 7A is an enlarged cross-sectional view of the  
4        countersunk, offset cover plate holes of Fig. 7.

5        Fig. 8 is an exploded perspective view of the final  
6        assembly of the free-space, slab laser of the present  
7        invention including heatsinked electronic circuit board and  
8        cooling fans.

9        Fig. 8A is a partial perspective of an alternative  
10       embodiment showing water cooled heatsinks.

11       Fig. 9 is an exploded perspective view of the adjustable  
12       mirror assembly on the front of the slab laser of the present  
13       invention of Fig. 5.

14       Fig. 10 is a cross sectional view of the front mirror  
15       mount assembly taken along the lines 10-10 of Fig. 9.

16       Fig. 11 is an exploded perspective of the rear adjustable  
17       mirror assembly of the present invention of Fig. 5.

18       Fig. 12 is a cross sectional view taken along the lines  
19       12-12 of Fig. 11.

20       Fig. 13 is a schematic view of a cross section of a first  
21       alternative embodiment of a free-space slab laser of the  
22       present invention.

23       Fig. 14 is a schematic view of a cross section of a  
24       second alternative embodiment of a free-space slab laser of  
25       the present invention.

1            Fig. 15 is a schematic view of a cross section of a third  
2            alternative embodiment of a free-space slab laser of the  
3            present invention.

4 IV. Detailed Description of the Preferred Embodiment

A. Free-Space Gas Slab Laser Of The Present Invention With  
Multi-Pass Resonator

7           The approach of the present invention, as initially seen  
8   in partial schematic form in Fig. 1, is to use a gas slab  
9   laser 10 with a stable resonator and to use the fundamental  
10  mode of the stable resonator. The result is the definition of  
11  a new type of a gas slab laser which is a non-waveguide, i.e.,  
12  free-space, laser in both directions.

As seen in schematic form in Fig. 1, the gas slab laser 10 includes a pair of parallel, elongated electrodes 11,12 defining a discharge area of height "a" and length "l" at the respective ends of which are reflective mirrors 14,15 of diameters d2, d1, respectively. The Gaussian beam 17 represents the fundamental mode of the stable slab laser resonator established in the discharge area when RF excitation 13 is applied. Mirror 15, the output coupler, is only partially reflective emitting laser light beam 16.

22           The parameters of the resonator and the size of  
23   electrodes are chosen as follows: the diameter of the  
24   fundamental mode of the resonator 10 should be less than the  
25   distance "a" between electrodes 11,12. For example, if the  
26   length of the slab is 500mm, the output coupler is flat and  
27   the total reflector has a 4.0m radius of curvature, then the

1 outside diameter of the fundamental mode (near the curved  
2 mirror) is about 4.5mm. So if we choose the distance between  
3 electrodes  $a = 5.0\text{mm}$ , and use the output coupler clear aperture  
4 of the same size - 5.0mm, then that laser can produce the  
5 fundamental mode. See Fig. 1.

6 In this case, however, the efficiency of utilizing the  
7 entire volume of active medium in the discharge area will be  
8 very low (e.g. about 30% if the width "b" of the slab  
9 (measured perpendicular to the paper in Fig. 1) where  $b = 15\text{mm}$ ).  
10 To increase the utilization efficiency of the active volume of  
11 the discharge area, we use a multi-pass resonator 30,50 (see  
12 Figs. 2,3). In Fig. 2 this resonator 30 includes three  
13 mirrors: concave back-end mirror (total reflector) 31 and two  
14 front flat mirrors 32,34 - one, the output coupler (a  
15 partially reflecting mirror) 32, and the other, an  
16 intermediate flat mirror (a total reflector) 34. The surface  
17 of the output coupler 32 is placed perpendicular to the  
18 optical axis of the system, the back mirror 31 and  
19 intermediate mirror 34 being slightly angled relative to the  
20 optical axis of the system so that the trajectory multi-pass  
21 reflection of the laser beam goes from mirror 32 then to  
22 mirror 31 from which it is reflected to mirror 34 from which  
23 it is reflected back to mirror 31 and then back to mirror 32  
24 in a multi-pass (two-pass) traverse of the active medium. The  
25 mirrors 31,32,34 are aligned so that after a number of  
26 reflections from the mirrors, the beam returns to its initial  
27 position on the surface of the output coupler and portion 33

1 is emitted. In this case the efficiency of the medium  
2 utilization is close to 90%.

3 In Fig. 3, resonator 50 operates similarly to resonator  
4 30 of Fig. 2, except that the number of passes changes from  
5 two (Fig. 2) to five and depends on the width "b" of the  
6 electrodes. Output coupler 52, emitting light beam 53, is  
7 partially reflective while back mirror 51 and intermediate  
8 mirror 54 are fully reflective. If  $a=5.0\text{mm}$ ,  $b=15\text{mm}$ , then it  
9 has been found that the optimal number of passes is five. In  
10 this case output power is a maximum. If  $a=7\text{mm}$ ,  $b=21\text{mm}$ , the  
11 distance between mirrors is  $500\text{mm}$  and the radius of curvature  
12 of the rear mirror is  $4\text{m}$ , then the optimal number of passes is  
13 eight or nine (not shown). It is important to note that if  
14 the output coupler 32,52 and intermediate mirror 34,54 are  
15 flat (or they have the same radius of curvature), then the  
16 structure of the output mode is the same as in the case of one  
17 pass and does not depend on the number of passes. The number  
18 of passes changes only the optimal reflection of the output  
19 coupler: the greater the number of passes the greater the  
20 overall gain, and, thus, the less the optimal coefficient of  
21 reflection of the output coupler in order to obtain the  
22 optimum power output. For example, for the single-pass  
23 resonator mentioned above, the optimum reflectivity is about  
24 92%, whereas for the five-pass resonator mentioned above the  
25 optimum reflectivity is about 70%.

26 B. Electrode-Spacers Sub-assembly

1           As best seen in Fig. 4, the electrode spacer sub-assembly  
2 90 of the present invention includes two electrodes 91,92 each  
3 of which has in cross section a T-shape comprising upright  
4 flat flange portions 93 and inwardly extending rectangular  
5 stem portions 94. The electrodes are made of aluminum having  
6 a thick insulative, hard, anodized coating of aluminum oxide  
7 in the range of .025mm-.01mm thick. On the inboard side of  
8 the vertical flange portion 93 of each electrode are a pair of  
9 recesses 95 at the top portion of flange 93 and a pair of  
10 recesses 95 at the bottom portion of flange 93. Each recess  
11 has a flat bottom edge 105. On the outboard side of the  
12 vertical flange portion 93 of each electrode are pairs of  
13 recesses 96 located about one quarter of the distance from  
14 each end of each electrode. Each recess of the pair of  
15 recesses 96 are spaced apart from each other so that they are  
16 close to the top and bottom outboard edges of each electrode  
17 91,92 to stabilize the electrode mounting.

18           When the electrodes are brought toward each other for  
19 assembly, a support ring 97 is fitted into each pair of  
20 opposing recesses 95 and functions as a deformable support  
21 member used to achieve the predetermined optimal spacing  
22 between the electrodes 91,92. Support members 97 are  
23 deformable rings. Each member 97 is physically deformed by  
24 turning screw 98 which deforms ring 97 by compressing opposing  
25 sides of the ring and thereby forcing the electrodes 91,92  
26 apart outwardly and forcing spacers 99 (described below)  
27 outwardly against their respective inside walls of the tube

1 111. In this manner the predetermined optimal spacing between  
2 the electrodes is obtained at the upper and lower ends thereof  
3 and at the front and rear ends thereof as viewed in Figs. 4,6,  
4 and the electrodes 91,92 are firmly and symmetrically  
5 supported within tube 111. Rings 97 are preferably made of  
6 aluminum and are also covered by an insulative, hard, anodized  
7 aluminum oxide coating. An alternative material such as  
8 stainless steel may also be used.

9 Little cylindrical spacers 99 are fitted into the pairs  
10 of recesses 96 on the outboard sides of electrodes 91,92 and  
11 establish a predetermined spacing between the outboard surface  
12 of the vertical flanges 93 of electrodes 91,92 and the inboard  
13 surfaces of the tube 111 (Figs. 4,6). The cylindrical spacers  
14 99 may have alternative shapes, such as, a ball or washer.  
15 The spacers 99 are preferably made from aluminum and may also  
16 have a hard, anodized, aluminum oxide coating. Alternative  
17 materials include ceramic or stainless steel.

18 RF feed mounting blocks 100 are secured to the upper  
19 inboard sides of the electrodes 91,92 by mounting screws 101  
20 through holes 102 and connect to RF terminals 103 which  
21 connect with the RF supply and which insulatively extend  
22 through the upper wall of tube 111. As described more fully  
23 below, the RF feeds also maintain the vacuum integrity of the  
24 tube 111 through a gas-tight seal effected therewith.

25 As best seen in Fig. 6, when the electrode-spacer  
26 assembly 90 is assembled inside tube 111, with spacers 99 in  
27 place in recesses 96 and support rings 97 supported in

1 recesses 95, screws 98 are turned clockwise to deform rings 97  
2 forcing electrodes 91,92 apart and cause spacers 99 to be held  
3 firmly in their recesses and against the inner walls of the  
4 tube 111 thereby laterally positioning the electrodes within  
5 the tube and having a gap 40 of predetermined narrow dimension  
6 "a". Rings 97 also have recesses 104 (Fig. 4) cut into their  
7 inboard edges such that the adjacent circumferential portions  
8 106 of rings 97 fit into recesses 95 and overly the bottom  
9 edge 105 (Fig. 4) of recesses 95. The vertical height of the  
10 adjacent circumferential portions 106 of rings 97 (Fig. 4) is  
11 of a predetermined height so as to extend above the top and  
12 bottom edges 108 of electrodes 91,92 providing a predetermined  
13 top and bottom spacing of the electrodes 91,92 from the inner  
14 top and inner bottom walls of tube 111 (as seen in Fig. 6)  
15 thereby vertically positioning the electrodes 91,92 within  
16 tube 111. In this manner the electrodes are positioned very  
17 close to, but insulatively spaced from, the inner walls of the  
18 tube 111. The preferred electrode-wall spacing is 0.5mm. By  
19 keeping the spacing between the electrodes and the tubes  
20 controlled (the larger the spacing, the smaller the  
21 capacitance), the electrode-tube inherent capacitance is kept  
22 at a minimum and does not interfere with the rapid initial  
23 excitation of the electrodes by the RF power source. On the  
24 other hand, the smaller the spacing, the greater the thermal  
25 conduction. The close proximity of the long flat outboard  
26 surfaces 93 of the electrodes to the inner walls of the tube  
27 111 provide good thermal conductivity. The laser gas mixture

1 is also selected to be rich in helium, a good thermal  
2 conductor. Accordingly, there is an optimal balance between  
3 material, spacing and gas in order to provide rapid start up  
4 of the laser and rapid removal of heat from the discharge area  
5 40 thereby contributing significantly to the cooling of the  
6 apparatus during operation.

7 The above construction assures a gap 40 of narrow  
8 dimension "a" and wide dimension "b" (Fig. 6) and length "l"  
9 as shown in schematic form in Fig. 1.

#### 10 C. Laser Tube Sub-assembly

11 As seen in Fig. 5 the laser tube sub-assembly includes  
12 the electrode spacers sub-assembly 90 of Fig. 4, the tube 111,  
13 the front dual mirror mount sub-assembly 120 and the rear  
14 mirror mount sub-assembly 150. Each of these sub-assemblies  
15 not previously discussed will be described further below.

16 Laser tube sub-assembly 110 is assembled first by  
17 inserting electrode-spacers sub-assembly 90 within tube 111  
18 and turning screws 98 clockwise to firmly secure electrode-  
19 spacers sub-assembly 90 within tube 111 in symmetrical, spaced  
20 relation to the inner walls of tube 111 as described above.  
21 RF feed terminals 103 are inserted through spacers 113 and  
22 insulative O-rings 112 and screw into corresponding threaded  
23 holes 107 atop RF feed mounting blocks 100 thereby further  
24 securing electrode-spacers sub-assembly 90 within tube 111  
25 adapted for connection to the RF supply 13.

26 As more clearly seen in Fig. 6, when terminal 103 is  
27 screwed into threaded hole 107, spacer 113 moves inwardly and

1 presses O-ring 112 against the top surface 112a of RF feed  
2 mounting block 100. O-ring 112 compresses and forms a seal  
3 against the inside wall 112b of the hole 114 in tube 111 and  
4 also against the outside diameter of the recess 112c of  
5 terminal 103. The seals are formed without putting any  
6 lifting force on the electrodes 91,92 due to the clearance fit  
7 between terminal 103 and spacer 113 in hole 114. Thus, the  
8 forces on electrodes 91,92 remain uniformly distributed.

9 1. Front Dual Mirror Mount Sub-assembly

10 As viewed in Fig. 5, the front dual mirror mount sub-  
11 assembly 120 is first sub-assembled before it is sealingly  
12 attached to close the front of tube 111. The sealing  
13 attachment of front mirror sub-assembly 120 to the front end  
14 of the tube 111 (and also the sealing attachment of rear  
15 mirror sub-assembly 150 to the rear end of tube 111) is  
16 preferably done by welding. However, it may also be  
17 accomplished by use of epoxy compound or an O-ring compressed  
18 by a screwed mounting.

19 As best seen in Figs. 5,9,10 front mirror mount sub-  
20 assembly 120 includes front end plate 121 having an O-ring  
21 recess 122 adapted to receive intermediate plate O-ring 125  
22 therein and having rectangular beam aperture 123 therein  
23 corresponding substantially to the gap 40 between electrodes  
24 91 and 92.

25 Intermediate mirror support plate 127 is secured to tube  
26 front end plate 121 via three adjusting screws 131a, 131b and  
27 131c inserted through corresponding mounting holes 130 in

1 support plate 127. Screws 131a, 131b and 131c are screwed  
2 into threaded holes 124 in front end plate 121 with annular  
3 ring 125a pressing against O-ring 125 in recess 122 forming a  
4 gas tight seal therebetween. (Fig. 10). At the same time,  
5 intermediate mirror 126 is captured in a recess in the inboard  
6 side of intermediate mirror support plate 127 (Fig. 10).

7 Screws 131a and 131c are orthogonal relative to screw 131b.

8 Mirror 126 is a totally reflector and is adjusted in a  
9 vertical plane about a horizontal axis via adjustment screw  
10 131a. Mirror 126 is adjusted in a horizontal plane about a  
11 vertical axis via adjustment screw 131c. Adjustments by  
12 rotating screws 131a, 131c, cause intermediate mirror support  
13 plate 127 to fulcrum in its respective plane about the point  
14 of attachment by fixed pivot screw 131b. O-ring 125 is  
15 respectively depressed as adjustments are made to 131a, 131c  
16 without breaking the seal.

17 Intermediate support plate 127 has a central aperture 128  
18 and an output coupler bracket O-ring recess 129 on its  
19 outboard side. Also formed therein are triangulated or  
20 orthogonal output coupler bracket screw holes 132. The output  
21 coupler 141 is mounted to the intermediate mirror support  
22 plate 127 using a triangular shaped output coupler bracket  
23 134. Bracket 134 is mounted against intermediate mirror  
24 support plate 127 such that annular ring 134a on the inboard  
25 side of output coupler bracket 134 (Fig. 10) presses against  
26 output coupler bracket O-ring 133 in recess 129 of support  
27 plate 127 making a gas tight seal therebetween. Output

1 coupler bracket 134 has central aperture 135 therein and, on  
2 its outboard side output coupler O-ring recess 136 to receive  
3 the output coupler O-ring 140 therein. Output coupler 141 is  
4 secured to the outboard side of output coupler bracket  
5 pressing against O-ring 140 by retainer 142 (Fig. 10) which is  
6 secured to the output coupler bracket 134 via the output  
7 retainer screws 143 mounted through holes 144 in the retainer  
8 142 and screwed into threaded holes 139 in output coupler  
9 bracket 134. Output coupler bracket 134 is secured to  
10 intermediate mirror support plate 127 by adjustment screws  
11 137a, 137b, 137c which extend through output coupler mounting  
12 screw holes 138 and are secured in the threaded output coupler  
13 bracket screw holes 132 on the outboard side of intermediate  
14 support plate 127. Screw 137b forms a fixed pivot point and  
15 screws 137a, 137c are orthogonal thereto allowing adjustment  
16 in a vertical plane about a horizontal axis via screw 137c and  
17 in a horizontal plane about a vertical axis via adjustment  
18 screw 137a. O-ring 133 is respectively compressed thereby  
19 allowing the output coupler 141 to be adjusted perpendicularly  
20 to the optical axis of the system.

21 As is well known in the art, alternative optical  
22 configurations are possible. One such alternative embodiment  
23 would combine the partially reflective, partially transmissive  
24 function of the output coupler mirror 141 with the totally  
25 reflective function of the intermediate mirror 126 into a  
26 single mirror, for example, having upper and lower portions  
27 dedicated to those separate functions.

1                                   2. Rear Mirror Mount Sub-assembly

2           Rear mirror mount sub-assembly 150, as best seen in Figs.  
3   5,11,12 includes a tube rear end plate 151 which sealingly  
4   closes the rear end of tube 111 and has a central aperture 152  
5   conforming generally to gap 40 and, on its outboard side, a  
6   rear mirror O-ring recess 153. Rear mirror O-ring 155 is  
7   seated in recess 153 and rear mirror bracket 157, carrying  
8   mirror 156, also a total reflector, in a recess on the inboard  
9   side thereof, is mounted to tube rear end plate 151 causing  
10   annular ring 157a to compress O-ring 155 in recess 153 to form  
11   a gas tight seal therebetween. (Fig. 12). Bracket 157 is  
12   secured to end plate 151 via rear mirror adjustment screws  
13   159a, 159b, 159c inserted through mounting holes 158 in  
14   bracket 157 and secured in threaded rear mirror mounting screw  
15   holes 154 in bracket 151. The same triangulated mirror  
16   adjustment mechanism is operable with respect to rear mirror  
17   156 as was effective for the two mirrors in the front end  
18   mount assembly 120. Here, the pivot screw is 159a with screws  
19   159b and 159c being affixed orthogonal thereto respectively in  
20   the horizontal and vertical planes to effect, respectively  
21   adjustments in the horizontal and vertical planes relative to  
22   pivot screw 159a.

23                                   D. Laser Tube-Heatsink Sub-assembly

24           As best seen in Fig. 7, tube and heatsink sub-assembly  
25   160 includes laser tube sub-assembly 110 of Fig. 5 together  
26   with heatsinks 161,162, cover plates 164,165, and O-rings 167.  
27   Heatsinks 161,162 are positioned laterally of tube assembly

1 110 and have cover plate mounting holes 163 formed in recesses  
2 on the top and bottom inboard edges of the heatsinks 161,162.  
3 Top and bottom cover plates 164,165 have a plurality of O-ring  
4 recesses 166 respectively on their inner surfaces. As best  
5 seen in Fig. 7A, holes 169 in cover plates 164,165 are  
6 countersunk and offset slightly inboardly relative to threaded  
7 mounting holes 163 in heatsinks 161,162. Cover plates 164,165  
8 are then secured via cover plate mounting screws 168 inserted  
9 through cover plate, countersunk mounting holes 169 and engage  
10 into offset threaded mounting holes 163 on the top and bottom  
11 edges of heatsinks 161,162. When screws 168 are tightened,  
12 they press against the outboard slanted edges of the offset  
13 countersunk holes 169 drawing heatsinks 162,163 inwardly  
14 firmly against the outboard walls of tube 111 and in good  
15 thermal contact therewith, capturing O-rings 167 in recesses  
16 166 and compressing the O-rings against the top and bottom  
17 surfaces, respectively, of the outboard surfaces of tube 111  
18 of tube assembly 110.

19 Accordingly, heatsinks 161,162 and cover plates 164,165  
20 form an integral circumferential structure around laser tube  
21 assembly 110 with heatsink 161,162 in good thermal contact  
22 with the side surfaces of tube 111, but cover plates 164,165  
23 flexibly spaced from the top and bottom surfaces of tube 111  
24 by compressed O-rings 167.

25 This mounting and cooling structure is unique and has  
26 been found to be especially beneficial in that there is no  
27 torsional distortion of the laser tube and cooling fins along

1 the length of the laser tube during operation as was the case  
2 with the prior art. In the present invention the heatsinks  
3 and cover plates are firmly secured together with the  
4 heatsinks firmly held against the sides of the laser, but, at  
5 the same time, the top and bottom cover plates being held in  
6 spaced relation to the laser top and bottom surfaces of the  
7 tube assembly 110, contacting it only through the compressed  
8 O-rings 167. Any similar flexible spacer may be used in place  
9 of O-ring 167. This structure permits variations in heating  
10 and expansion to take place in the tube 111 while minimizing  
11 torsional stresses which tend to distort the elongated  
12 rectangular shape of the overall assembly and displace the  
13 mirrors. At the same time, however, the spacing between tube  
14 111 and the flexibly connected cover plate-heatsink enclosure  
15 is small enough such that the heat conductivity from the laser  
16 tube assembly 110 through the directly contacting heatsinks  
17 161,162 is more than adequate to assure proper and effective  
18 cooling of all components.

19 E. Final Gas Laser Assembly

20 As best seen in Fig. 8, final gas laser assembly 200  
21 includes the tube and heatsink sub-assembly 160 of Fig. 8,  
22 electronics sub-assembly 170, and two fan sub-assemblies  
23 190,191.

24 Electronics sub-assembly 170 includes several  
25 conventional electronics printed circuit boards 171 supporting  
26 several discrete devices and additional conventional  
27 electronics components, including, but not limited to, an RF

1 generator having a matching impedance network 172 and other  
2 control electronics. These components are securely attached  
3 together in operative relation and secured between a pair of  
4 finned heatsinks 176,177 to form an electronics sub-assembly  
5 170. A cover plate 178 secures to its upper side via cover  
6 plate mounting screws 179 through cover plate mounting screw  
7 holes 180 in recesses at the upper end of heatsinks 176,177 to  
8 form electronics sub-assembly 170. This sub-assembly 170 is  
9 secured to tube and heatsink sub-assembly 160 via end plates  
10 181,182 and end plate screws 184 which extend through end  
11 plate screw holes 185 and then into threaded holes 186 in the  
12 ends of sub-assemblies 160,170. Thus, sub-assemblies 160,170  
13 are locked together by end plates 181,182. Fan sub-assemblies  
14 190,191 are mounted against the linked heatsinks and secured  
15 thereto via mounting screws 192 which screw into threaded  
16 mounted screw holes 193 in the side surfaces of the heatsinks  
17 161,162, 176,177. End plate 181 has aperture 183 through  
18 which the portion of the laser beam transmitted by the output  
19 coupler mirror 141 passes and is allowed to exit the system.

20 By covering the outsides of the heatsinks with fan sub-  
21 assemblies 190,191, the finned heatsinks are effectively made  
22 into a plurality of elongated channels through which the air  
23 is longitudinally pushed when the fans are activated. The  
24 pushed air exits simultaneously from each end of finned  
25 heatsinks 161,162,176,177. Heat is effectively removed from  
26 the system by this cooling mechanism and all components are  
27 maintained in safe thermal operating condition.

1           As seen in Fig. 8A, an alternative cooling structure  
2           would include a water cooled system. Instead of enclosed air  
3           channels formed by fins 161,162,176,177 and fan sub-assemblies  
4           190,191 as described above, these structures would be replaced  
5           by similar box-like structures 161a,162a containing tubing  
6           through which cooled water could be circulated from an  
7           external supply which includes a heat exchanger for cooling  
8           the water. Water cooled systems have the advantages over air  
9           cooled systems of quieter operation by placing the cooling  
10          apparatus in a separate room, absence of blowing germ-carrying  
11          air enabling a variety of otherwise foreclosed medical  
12          applications, and improved temperature control.

13          Figs. 13-15 show alternative constructions of the  
14          electrode system which may be used as desired. The preferred  
15          structure has been already described above.

16          Fig. 13 shows a pair of elongated base plates 300 secured  
17          within housing 301 by set screws 302 at the top and bottom of  
18          each of the front and rear ends, respectively, of the base  
19          plates. Set screws 302 are tightened by reaching into the end  
20          of the tube 301 with an allen wrench during assembly since set  
21          screws 302 are located adjacent the outer ends of the  
22          electrodes. In this embodiment each base plate 300 has  
23          secured thereto by any conventional means a plurality of  
24          elongated plates 303,304,305 to the inboard one of which is  
25          secured thereto by any conventional means one electrode 306  
26          spaced a predetermined distance from the other electrode 306  
27          similarly secured to the other base plate 300 via other

1 similar plates 305,304,303. Because base plates 300 are in  
2 electrical contact with the housing 301 through set screws  
3 302, spacers 303,304,305 are made insulative, such as  
4 preferably from anodized aluminum. RF feeds 13 connect via  
5 terminals 103 to electrodes 306. This embodiment does not use  
6 any mechanism to forcibly spread the electrodes apart to  
7 maintain them in a predetermined spaced relation. The use of  
8 multiple plates 303,304,305 in series increases thermal  
9 conductivity and decreases what would otherwise be an inherent  
10 large capacitance.

11 Fig. 14 presents yet another embodiment of the invention  
12 in which similar base plates 300 are secured by conventional  
13 means to housing 301 and support electrodes 306 in spaced  
14 relation to each other on insulative spacers 303 secured by  
15 conventional means to base plates 300 and into which have been  
16 milled grooves 303a and 303b on either side. The smaller  
17 electrodes and the grooves help to reduce the overall  
18 capacitance while maintaining good thermal conductivity.

19 Fig. 15 is yet another embodiment of the present  
20 invention in which larger electrodes 306 are directly  
21 conventionally secured to base plates 300 which are  
22 conventionally secured to housing 301. Grooves 306a are  
23 milled in the outboard side of electrodes 306 to help reduce  
24 the capacitance of the larger electrodes. Figs. 14 and 15  
25 respectively show improved operating characteristics over Fig.  
26 13. However, the optimal configuration is shown in Fig. 6.

27

1                                   F. Working Model

2           The specifications of a working model are as follows:

3                                   a = 5.0mm.

4                                   b = 15.0m.

5                                   l = 444.5mm.

6                                   RF power input = 300 Watts.

7                                   Frequency = 40.6 MHZ.

8                                   Output power = 25-30 Watts.

9                                   Wavelength = 10.6 microns.

10                                  Ambient temperature = 25<sup>0</sup>C.

11                                  Air cooled at 200 cfm airflow (100 cfm on each side).

12                                  The gas mixture is carbon dioxide, nitrogen and helium in  
13 the proportions 1:1:7 and 5% xenon by percent volume with a  
14 total pressure between 25-100 torr.

15                                  The preferred material for making the tube, the fins and  
16 the cover plates is aluminum because of its good thermal  
17 conductivity, low cost, and ease of manufacturing.

18                                  The foregoing description of a preferred embodiment and  
19 best mode of the invention known to applicant at the time of  
20 filing the application has been presented for the purposes of  
21 illustration and description. It is not intended to be  
22 exhaustive or to limit the invention to the precise form  
23 disclosed, and obviously many modifications and variations are  
24 possible in the light of the above teaching. The embodiment  
25 was chosen and described in order to best explain the  
26 principles of the invention and its practical application to  
27 thereby enable others skilled in the art to best utilize the

1 invention in various embodiments and with various  
2 modifications as are suited to the particular use  
3 contemplated. It is intended that the scope of the invention  
4 be defined by the claims appended hereto.

Claims

We claim:

- 1       1.    A gas slab laser characterized by;  
2            a gas containment structure,  
3            a pair of parallel, electrically insulated  
4    electrodes mounted in the gas containment structure and  
5    forming a gas discharge area having substantially a  
6    rectangular cross section,  
7            a laser gas mixture sealed in the gas containment  
8    structure,  
9            an RF feed terminal coupled to each electrode and  
10   adapted to couple to a source of RF-excitation, and  
11           an arrangement of reflective optical elements  
12   mounted to opposite ends of the gas containment structure  
13   adapted to form a laser resonator,  
14           the minimum distance between the electrodes being  
15   not less than the maximum cross-sectional size of a  
16   fundamental mode of a stable laser resonator operable  
17   substantially as a free-space laser resonator in any direction  
18   within the discharge area.
- 1       2.    The gas slab laser of claim 1 wherein each electrode  
2    is an elongated, T-shaped electrode made of anodized aluminum  
3    having an aluminum oxide coating in the range of about .025-  
4    .01mm.
- 1       3.    The gas slab laser of claim 1 wherein the laser gas  
2    is a mixture of CO<sub>2</sub>:N<sub>2</sub>:He approximately in the proportions of

3 1:1:7 plus 5% Xe by percent volume with a total pressure  
4 between 25-100 torr.

1 4. The gas slab laser of claim 1 wherein each RF feed  
2 terminal coupling is further characterized by:

3 the gas containment structure having an aperture  
4 through which the terminal extends with a clearance fit, and  
5 an O-ring compressed between the electrode, the RF  
6 terminal and the gas containment structure to seal the gas  
7 containment structure without applying any substantial force  
8 to the electrode.

1 5. The gas slab laser of claim 1 wherein the reflective  
2 optical elements are further characterized by:

3 at least one optical element with a concave  
4 reflective surface.

1 6. The gas slab laser of claim 1 wherein the reflective  
2 optical elements are further characterized by:

3 an output coupler which is partially reflective.

1 7. The gas slab laser of claim 1 wherein the reflective  
2 optical elements form a multi-pass laser resonator having at  
3 least two optical elements.

1 8. The gas slab laser of claim 7 wherein the multi-pass  
2 laser resonator is further characterized by :

3 one partially reflective optical element with a  
4 coefficient of reflection which is a function of the number of  
5 passes in the multi-pass resonator.

1 9. The gas slab laser of claim 1 wherein the  
2 arrangement of optical elements includes an optical assembly

3 at each end of the gas containment structure wherein each  
4 optical assembly is further characterized by:

5 an end plate closing the end of the gas containment  
6 structure having an aperture therein,

7 a first support plate secured to the end plate at a  
8 pivot point,

9 at least one reflective mirror affixed to the first  
10 support plate and aligned with the aperture in the end plate  
11 to receive and reflect light from the discharge area,

12 an O-ring compressed between the end plate and the  
13 first support plate sealing the gas containment structure,

14 the first support plate being adjustable about a  
15 vertical axis by a screw in a horizontal plane with the pivot  
16 point and about a horizontal axis by a screw in a vertical  
17 plane with the pivot point.

1 10. The gas slab laser of claim 9 wherein the mirror is  
2 a total reflector.

1 11. The gas slab laser of claim 9 wherein the mirror is  
2 an output coupler which is partially reflective and partially  
3 transmissive.

1 12. The gas slab laser of claim 9 wherein the mirror is  
2 an output coupler having one portion which is partially  
3 reflective and another portion which is totally reflective.

1           13. The gas slab laser of claim 9 wherein one of the  
2 optical assemblies is at the front end of the gas containment  
3 structure and is further characterized by:

4               a second support plate having an aperture therein  
5 and secured to the first support plate at a pivot point,

6               a second reflective mirror affixed to the second  
7 support plate and aligned with the aperture therein to  
8 receive and reflect light from the discharge area and to  
9 transmit light outside the gas containment structure,

10              an O-ring compressed between the first support plate  
11 and the second support plate sealing the gas containment  
12 structure,

13              the second support plate being adjustable about a  
14 vertical axis by a screw in a horizontal plane with the pivot  
15 point and about a horizontal axis by a screw in a vertical  
16 plane with the pivot point.

1           14. The gas slab laser of claim 1 wherein the cross-  
2 section of the fundamental mode is substantially round.

1           15. The gas slab laser of claim 14 wherein the minimum  
2 distance is about 5.0mm.

1           16. The gas slab laser of claim 1 further characterized  
2 by:

3           a plurality of rigid, deformable support members  
4   mounted between the electrodes for maintaining the spatial  
5   relationship of the electrodes.

1           17. The gas slab laser of claim 16 wherein each  
2   deformable support member is further characterized by:  
3           a ring, and  
4           a screw engaging opposite sides of the ring for  
5   compressing the opposite sides in one direction to spread the  
6   electrodes in another direction until the electrodes are  
7   firmly secured within the containment structure.

1           18. The gas slab laser of claim 16 wherein the  
2   deformable members are made of anodized aluminum.

1           19. The gas slab laser of claim 1 further characterized  
2   by:  
3           a plurality of short cylindrical spacers with a  
4   small cross-section maintaining the electrodes in spaced  
5   relation to the inner walls of the gas containment structure  
6   while providing minimal capacitance.

1           20. The gas slab laser of claim 1 further characterized  
2   by:  
3           each electrode having a large surface portion  
4   supported in close proximity to the inner wall of the gas  
5   containment structure to facilitate heat transfer,

6           a pair of elongated heatsinks contiguous those outer  
7   surfaces of the gas containment structure which are adjacent  
8   the large surface portions of the electrodes inside the gas  
9   containment structure,

10          a pair of cover plates each of which is secured to  
11   each heatsink, and

12          a plurality of flexible spacers between the cover  
13   plates and the gas containment structure,

14          the heatsinks and cover plates forming a flexibly  
15   mounted enclosure surrounding the gas containment structure  
16   allowing uniform heat transfer while eliminating thermal  
17   expansion forces tending to deform the gas containment  
18   structure.

1           21. The gas slab laser of claim 20 further characterized  
2   by:

3           the heatsinks having a plurality of threaded holes,  
4   and,

5           the cover plates having a plurality of countersunk  
6   holes offset slightly inwardly from the threaded holes,

7           whereby when the cover plates are secured to the  
8   heatsinks by screws through the countersunk holes, the  
9   heatsinks are drawn snugly against the gas containment  
10   structure surfaces while the flexible spacers are compressed  
11   and position the cover plates in close spaced relation to the  
12   gas containment structure.

1           22. The gas slab laser of claim 21 further characterized  
2 by:

3           an assembly of electronic components mounted on the  
4 flexibly mounted enclosure and coupled to the RF terminals,  
5 and

6           a fan assembly covering each heatsink forming a  
7 plurality of air channels for removing heat from the gas  
8 containment structure and electronic components.

1           23. The gas slab laser of claim 21 further comprising:  
2           a hollow tube disposed within each heatsink for  
3 passing coolant liquid therethrough for removing heat from the  
4 gas containment structure.

1           24. In a gas slab laser having a pair of parallel,  
2 elongated electrically insulated electrodes mounted in a  
3 housing and forming a gas discharge area having a rectangular  
4 cross section, a laser gas mixture sealed in the housing, an  
5 RF feed terminal coupled to each electrode and adapted to  
6 couple to a source of RF-excitation, and an arrangement of  
7 reflective optical elements mounted to opposite ends of the  
8 housing adapted to form a laser resonator operable in the  
9 discharge area when RF excitation is applied,

1           wherein the improvement is characterized by:

2           a plurality of rigid, deformable support members  
3 mounted between the electrodes for maintaining the spatial  
4 relationship of the electrodes.

1           25. The gas slab laser of claim 25 wherein each  
2 deformable support member is further characterized by:  
3           a ring, and  
4           a screw engaging opposite sides of the ring for  
5 compressing the opposite sides in one direction to spread the  
6 electrodes in another direction until the electrodes are  
7 firmly secured within the housing.

1           26. In a gas slab laser having a pair of parallel,  
2 elongated electrically insulated electrodes mounted in a  
3 housing and forming a gas discharge area having a rectangular  
4 cross section, a laser gas mixture sealed in the housing, an  
5 RF feed terminal coupled to each electrode and adapted to  
6 couple to a source of RF-excitation, and an arrangement of  
7 reflective optical elements mounted to opposite ends of the  
8 housing adapted to form a laser resonator operable in the  
9 discharge area when RF excitation is applied,  
10          wherein the improvement is characterized by:  
11           each electrode having a large surface portion  
12 supported in close proximity to the inner wall of the housing  
13 to facilitate heat transfer,  
14           a pair of elongated heatsinks contiguous those outer  
15 surfaces of the housing which are adjacent the large surface  
16 portions of the electrodes inside the housing,  
17           a pair of cover plates each of which is secured to  
18 each heatsink, and

19           a plurality of flexible spacers between the cover  
20 plates and the housing,

21           the heatsinks and cover plates forming a flexibly  
22 mounted enclosure surrounding the housing allowing uniform  
23 heat transfer while eliminating thermal expansion forces  
24 tending to deform the housing.

1           27. The gas slab laser of claim 27 further characterized  
2 by:

3           the heatsinks having a plurality of threaded holes,  
4 and

5           the cover plates having a plurality of countersunk  
6 holes offset slightly inwardly from the threaded holes,

7           whereby when the cover plates are secured to the  
8 heatsinks by screws through the countersunk holes, the  
9 heatsinks are drawn snugly against the housing surfaces while  
10 the flexible spacers are compressed and position the cover  
11 plates in close spaced relation to the housing.

1           28. In a gas slab laser having a pair of parallel,  
2 elongated electrically insulated electrodes mounted in a  
3 housing and forming a gas discharge area having a rectangular  
4 cross section, a laser gas mixture sealed in the housing, an  
5 RF feed terminal coupled to each electrode and adapted to  
6 couple to a source of RF-excitation, and an arrangement of  
7 reflective optical elements mounted to opposite ends of the  
8 housing adapted to form a laser resonator operable in the  
9 discharge area when RF excitation is applied,

10           wherein the improvement is characterized by:

11           each electrode having a large surface portion  
12 supported in close proximity to the inner wall of the housing  
13 to facilitate heat transfer,

14           a first pair of elongated heatsinks contiguous those  
15 outer surfaces of the housing which are adjacent the large  
16 surface portions of the electrodes inside the housing,

17           an assembly of electronic components coupled to the  
18 RF terminals and mounted between a second pair of elongated  
19 heatsinks which are juxtaposed the first pair of heatsinks,  
20 and,

21           a plurality of cover plates securing the first and  
22 second pairs of heatsinks together and forming an enclosure  
23 surrounding the heatsinks and electronic components and a  
24 plurality of air channels in the heatsinks for removing heat  
25 from the housing and electronic components, and

26           a fan communicating with the air channels of each  
27 heat sink to force air through the channels to remove heat  
28 from the housing.

1           29. In a gas slab laser having a pair of parallel,  
2 elongated electrically insulated electrodes mounted in a  
3 housing and forming a gas discharge area having a rectangular  
4 cross section, a laser gas mixture sealed in the housing, an  
5 RF feed terminal coupled to each electrode and adapted to  
6 couple to a source of RF-excitation, and an arrangement of  
7 reflective optical elements mounted to opposite ends of the

8 housing adapted to form a laser resonator operable in the  
9 discharge area when RF excitation is applied,  
10 wherein the improvement is characterized by:  
11 each electrode having a large surface portion  
12 supported in close proximity to the inner wall of the housing  
13 to facilitate heat transfer,  
14 a first pair of elongated heatsinks contiguous those  
15 outer surfaces of the housing which are adjacent the large  
16 surface portions of the electrodes inside the housing,  
17 an assembly of electronic components coupled to the  
18 RF terminals and mounted between a second pair of elongated  
19 heatsinks which are juxtaposed the first pair of heatsinks,  
20 a plurality of cover plates securing the first and  
21 second pairs of heatsinks together and forming an enclosure  
22 surrounding the heatsinks and electronic components, and  
23 a hollow tube disposed within each heatsink for  
24 passing coolant liquid therethrough for removing heat from the  
25 housing and electronic components.

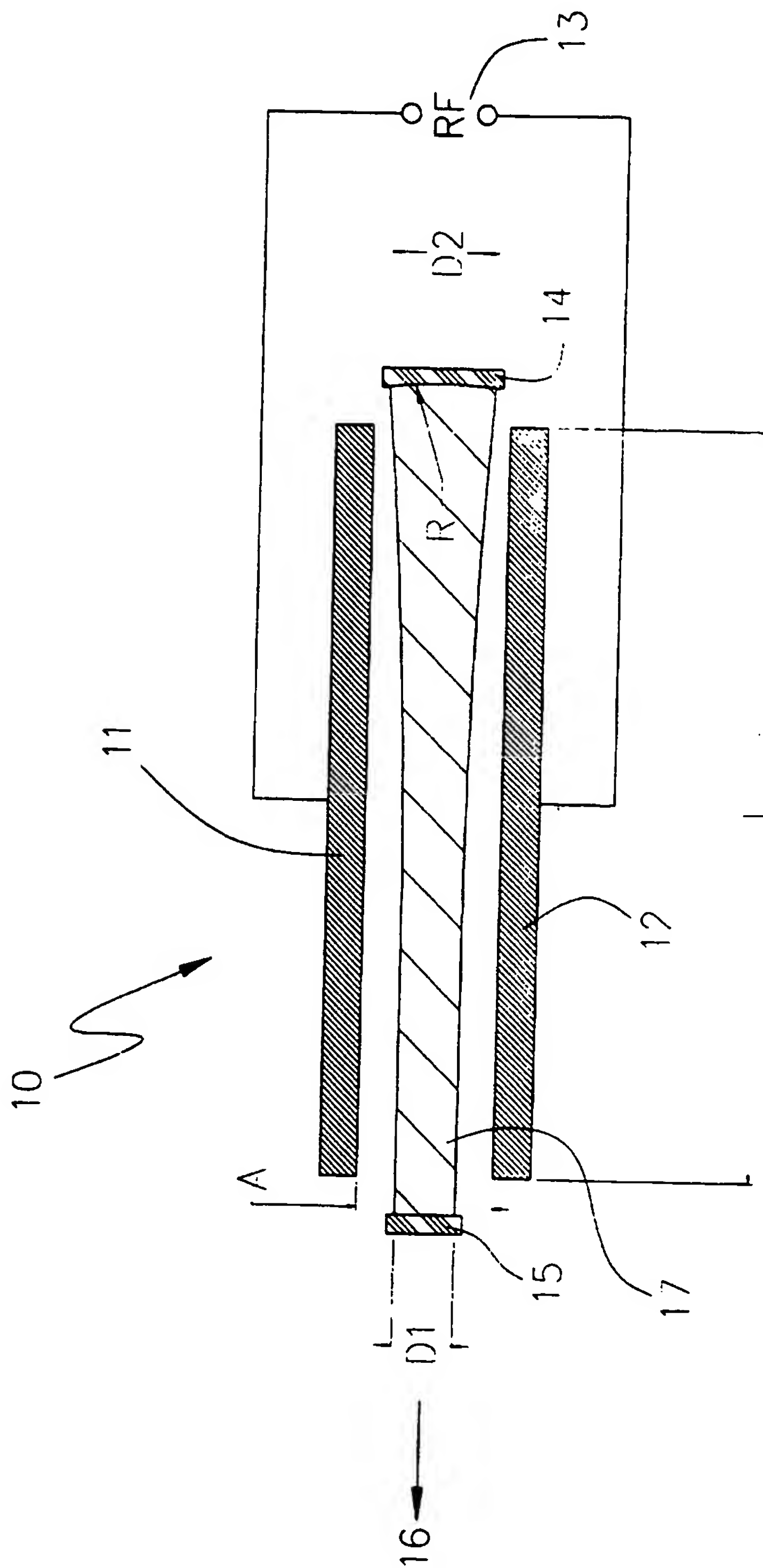


FIG 1

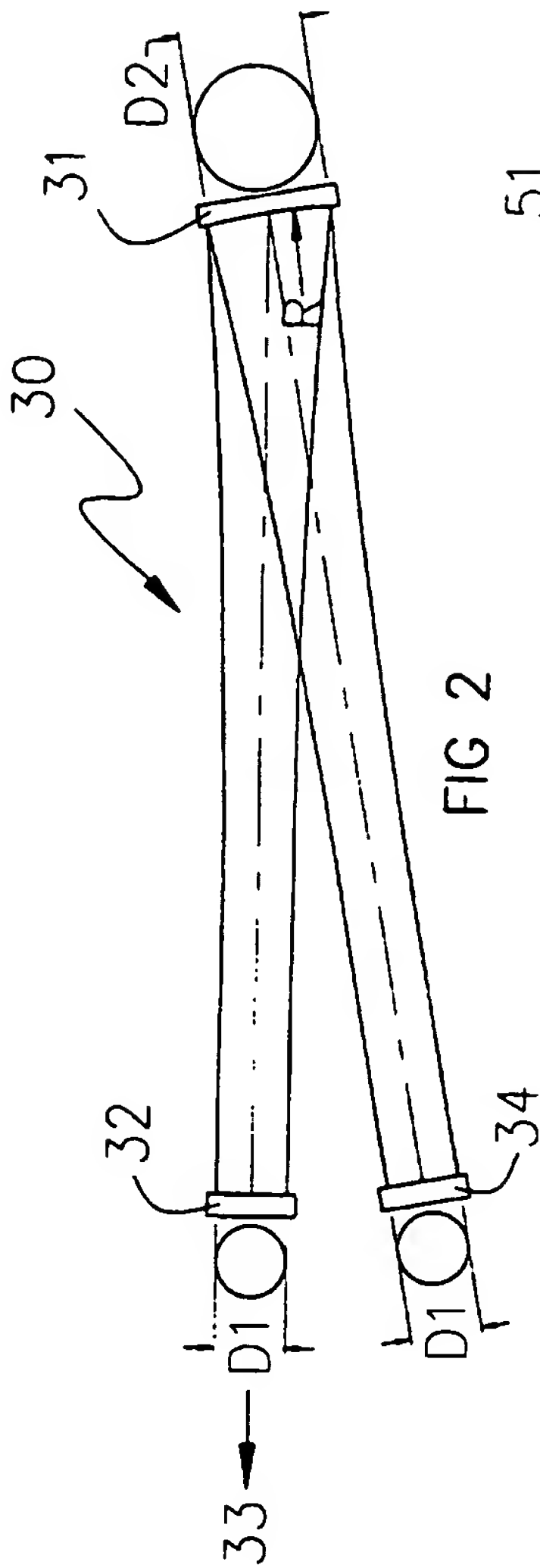


FIG 2

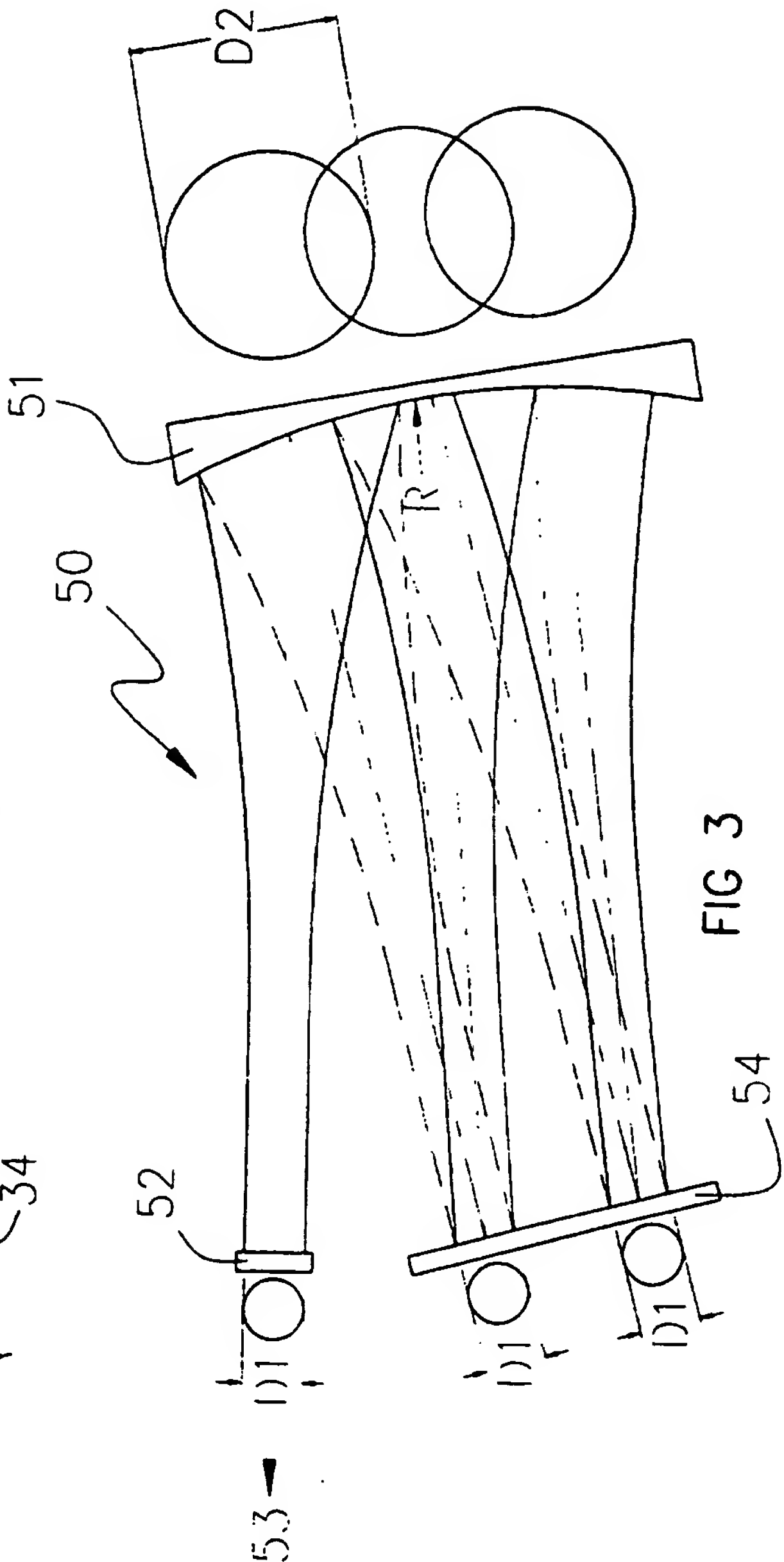


FIG 3

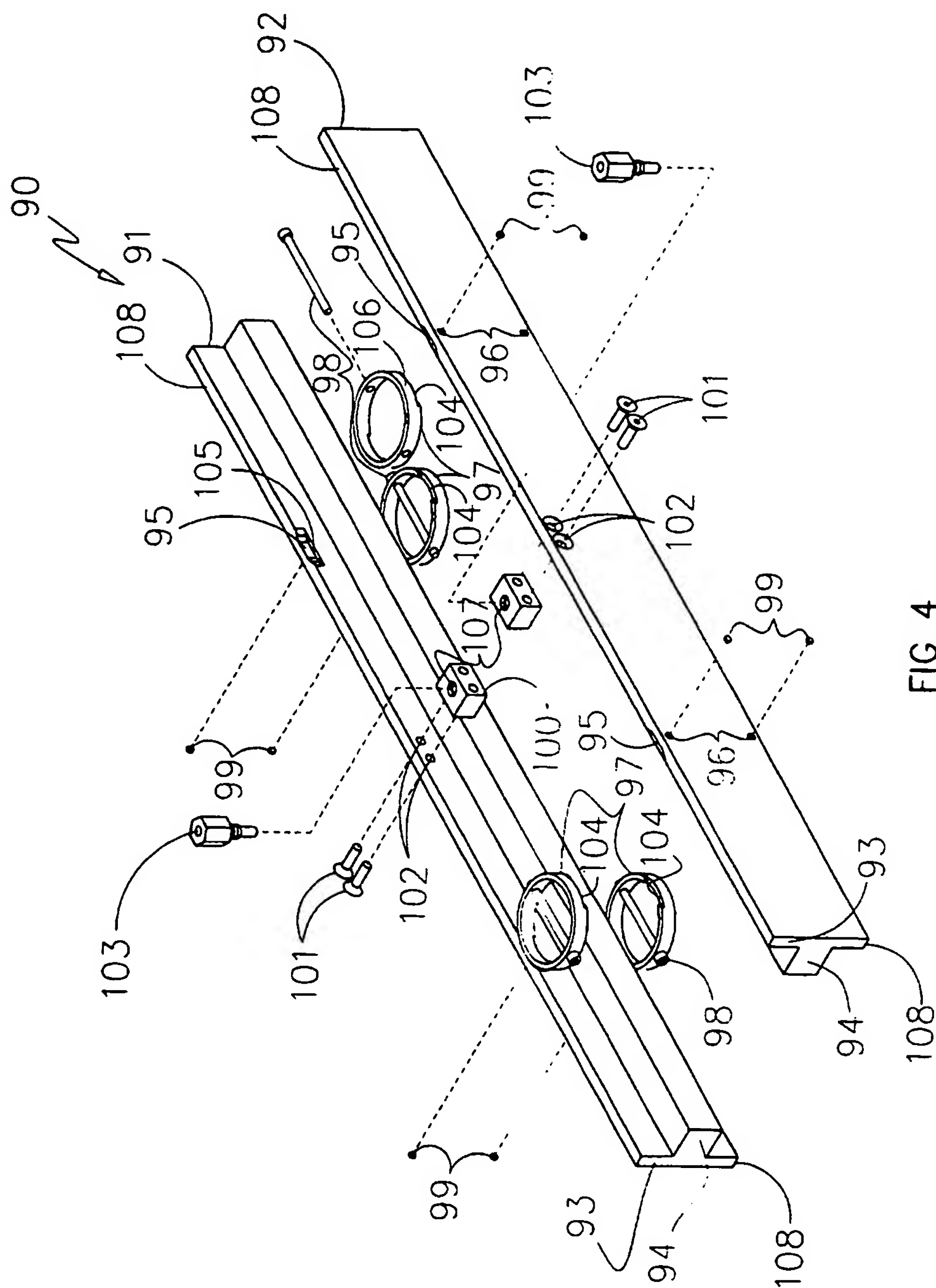
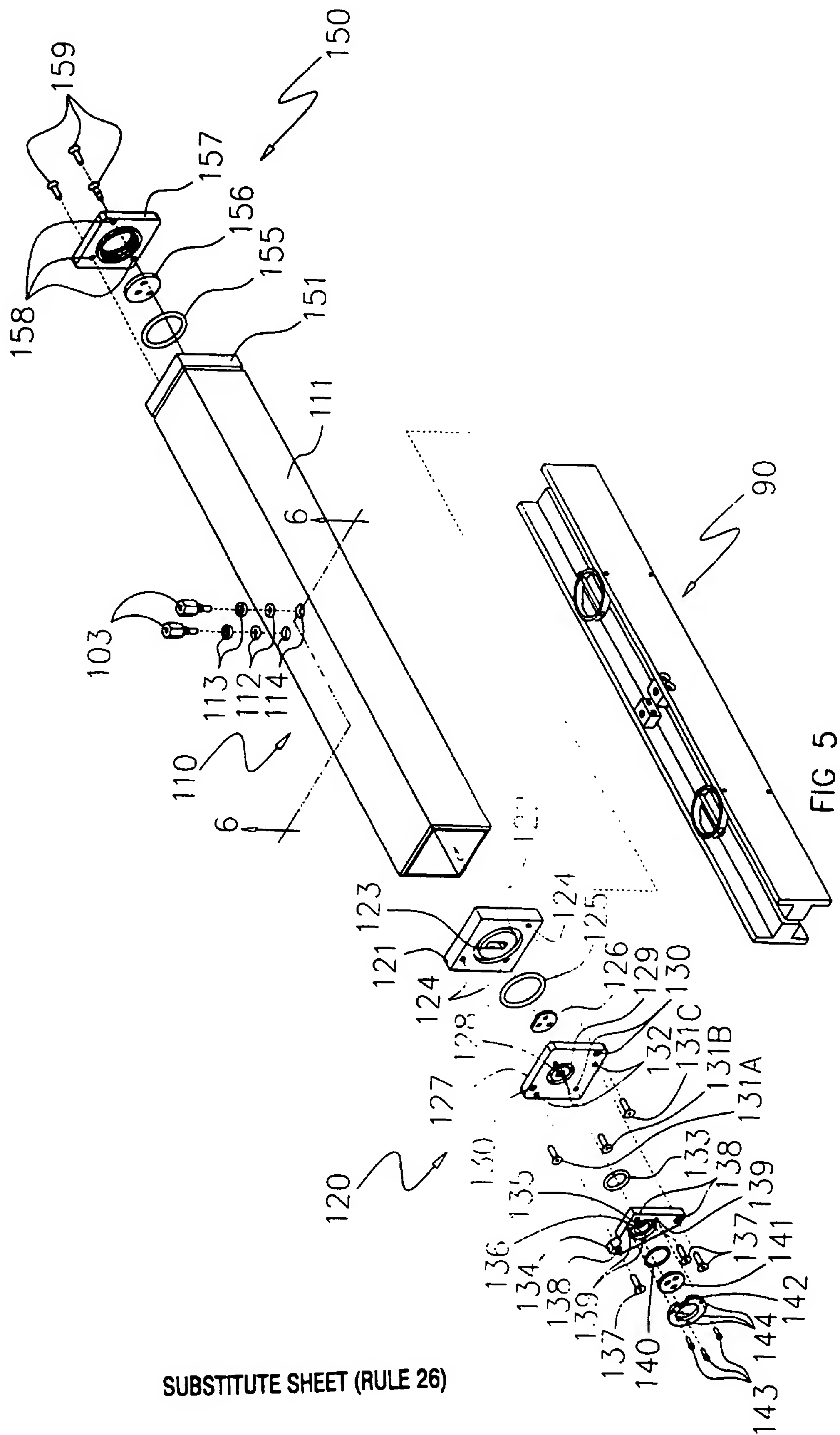


FIG 4



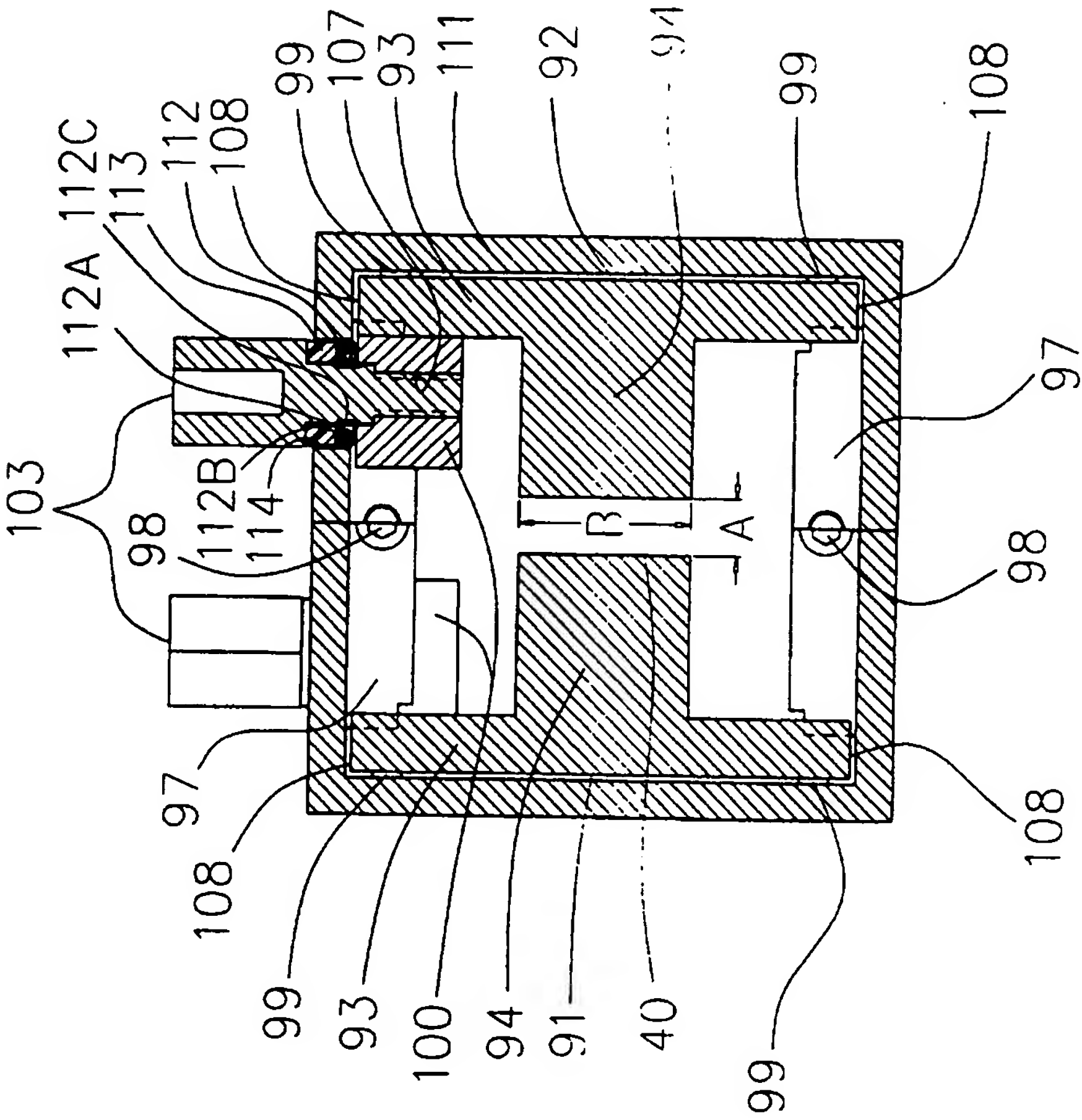
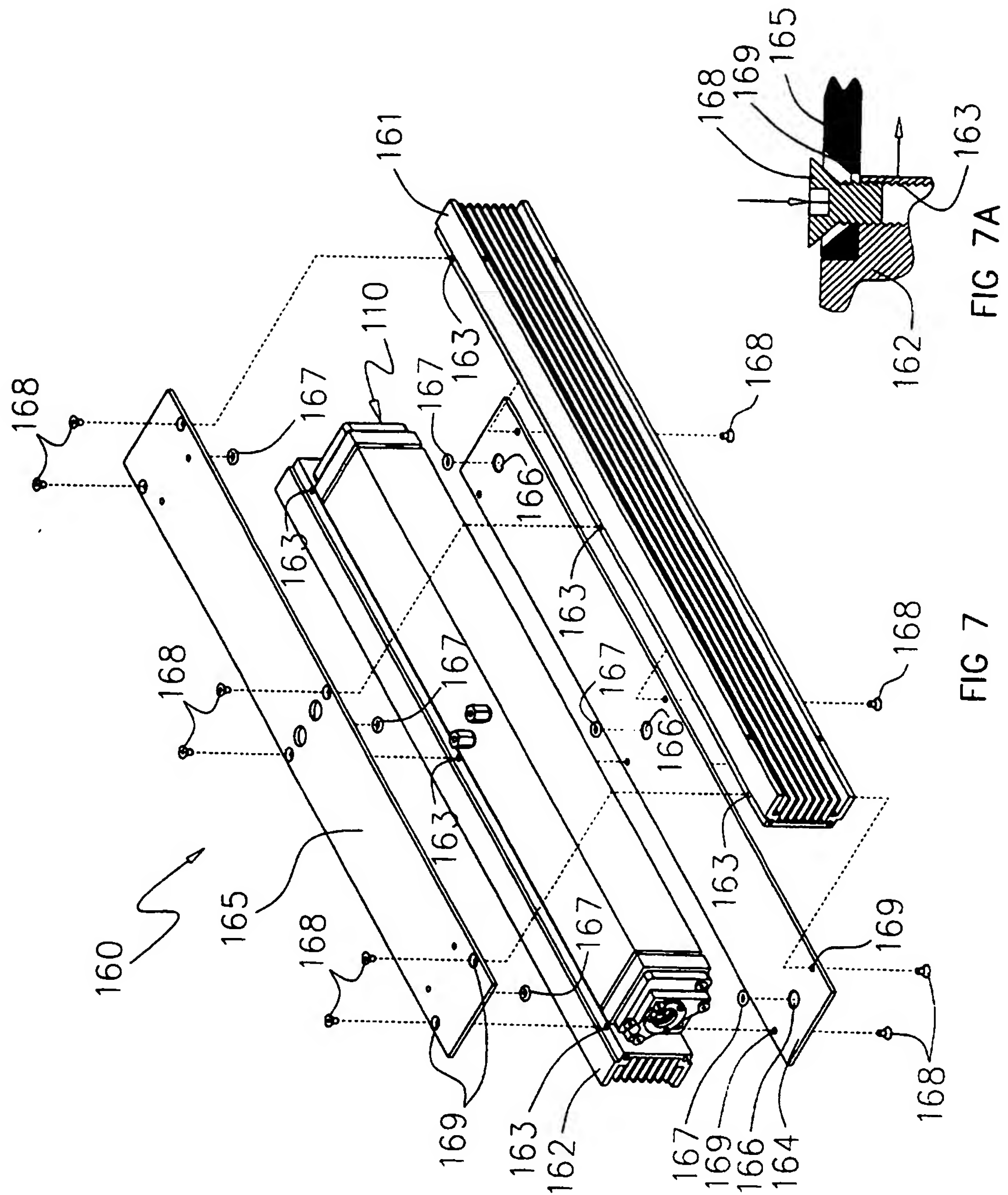
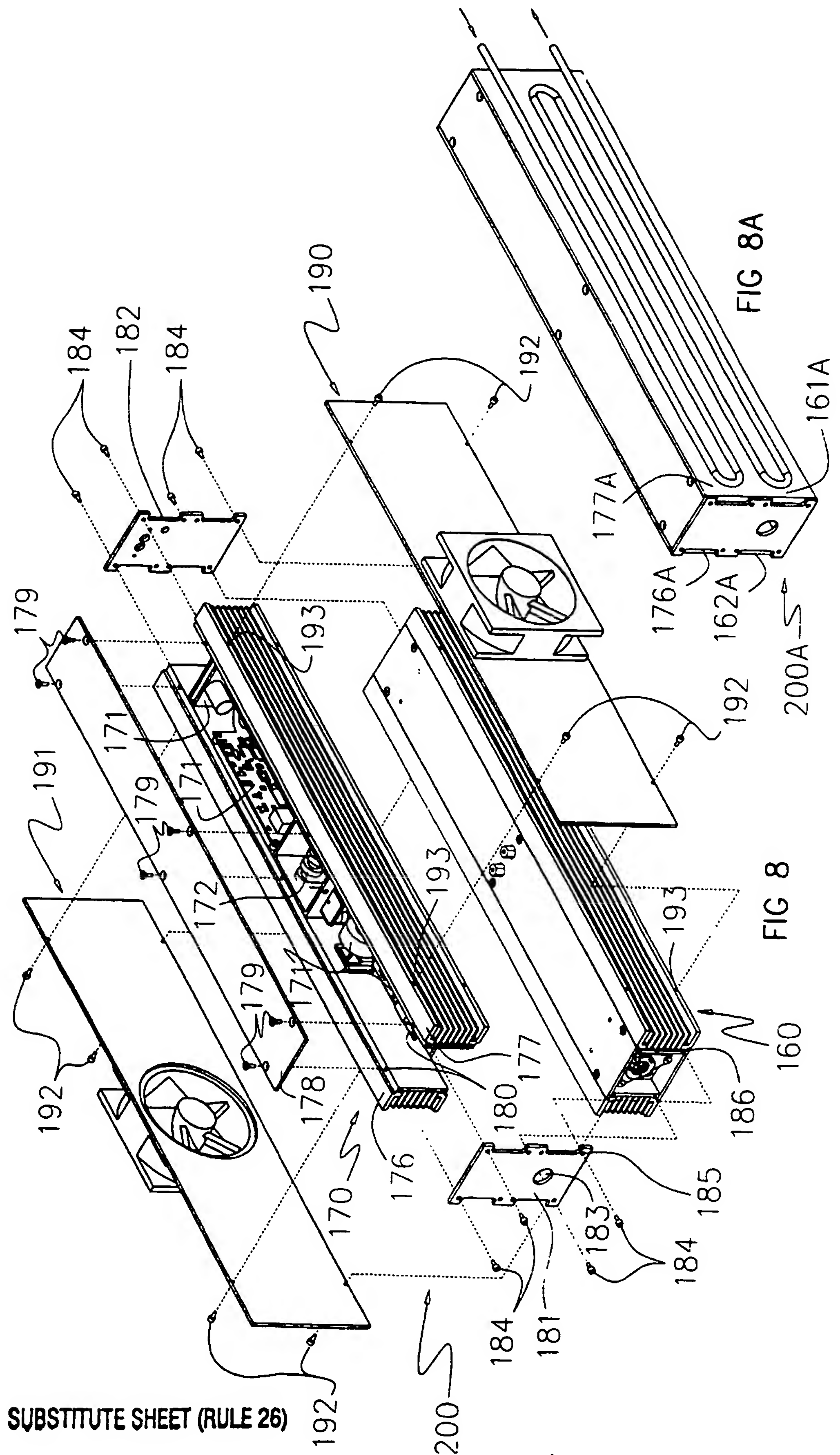
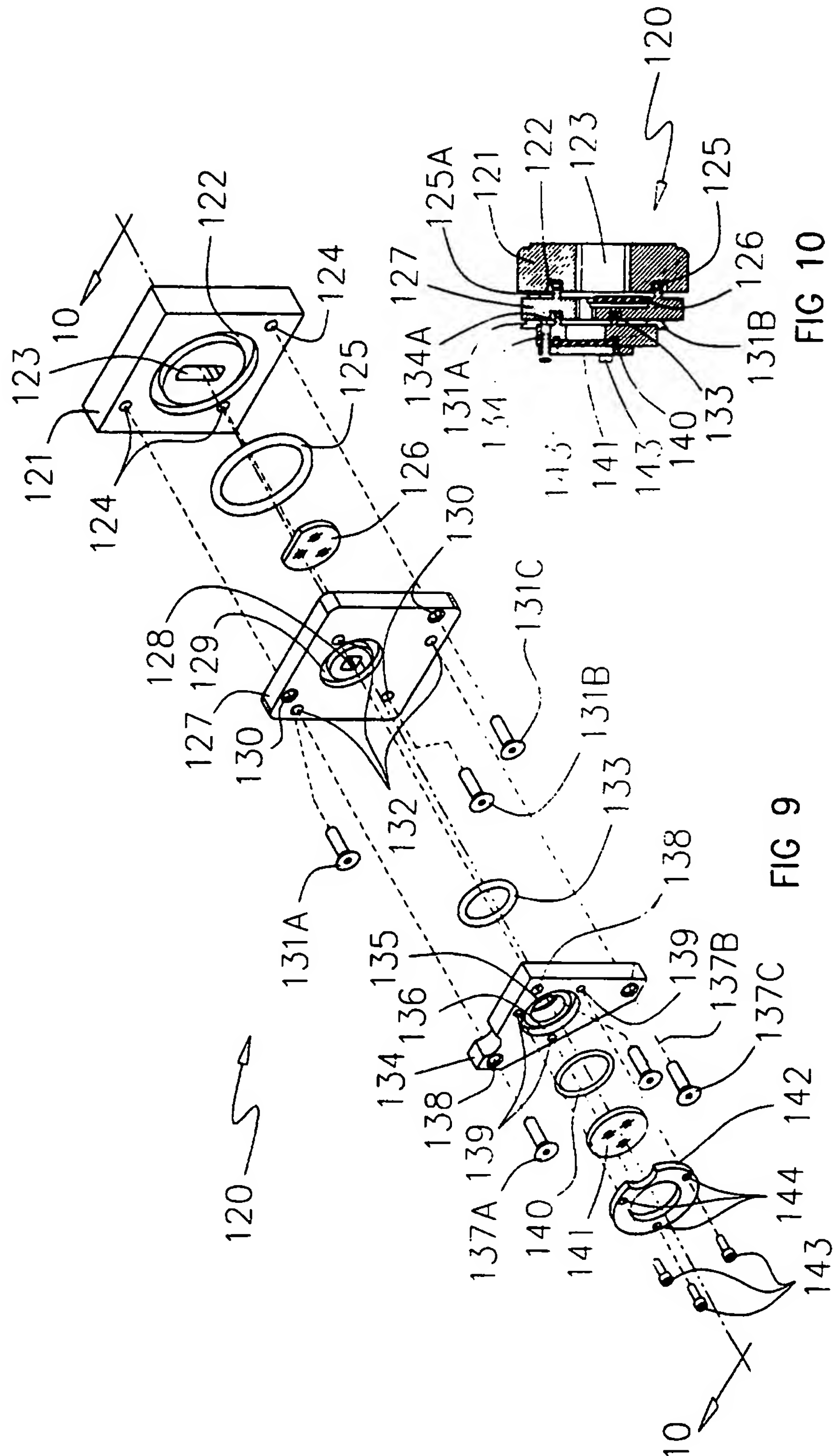
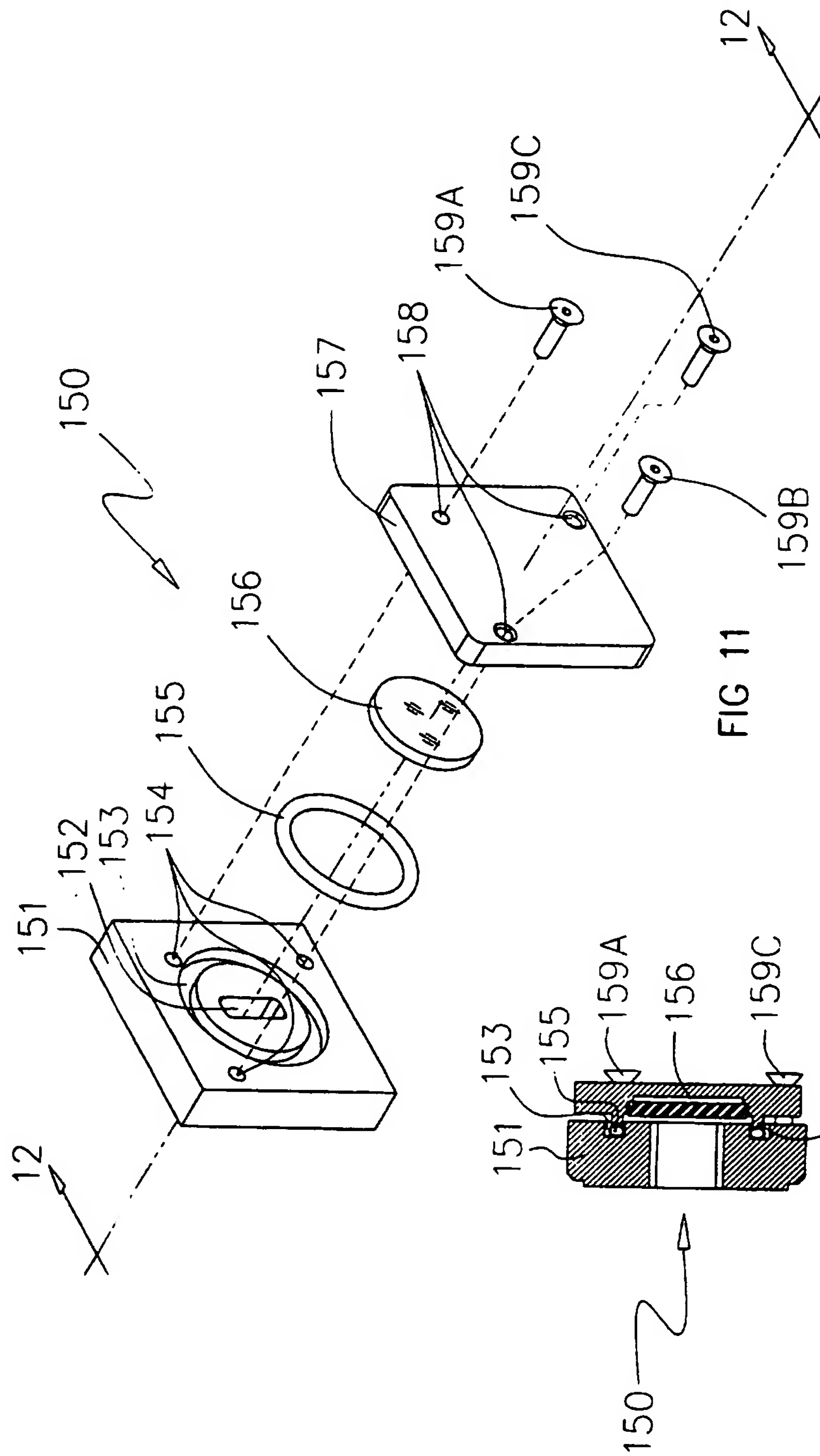


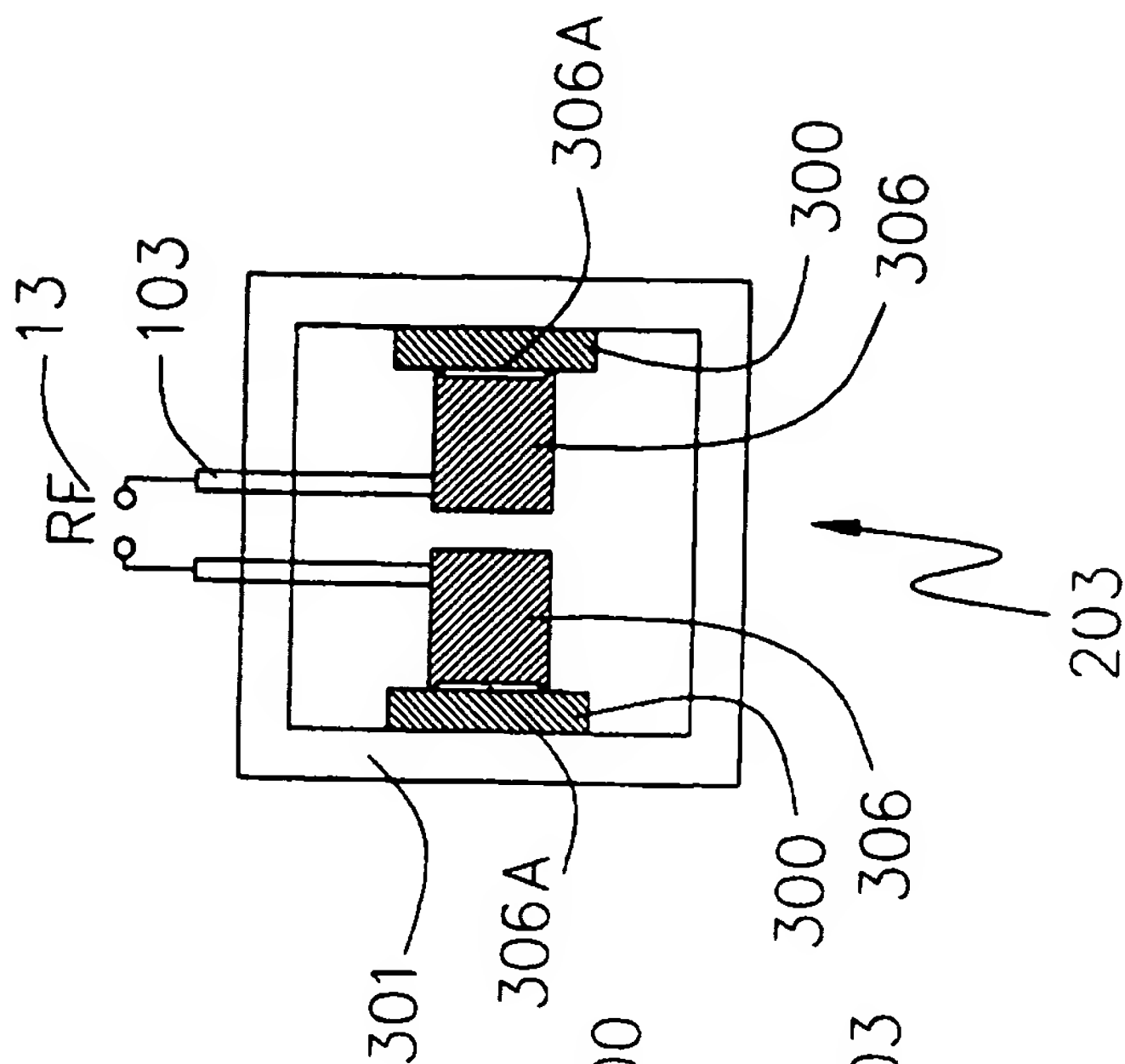
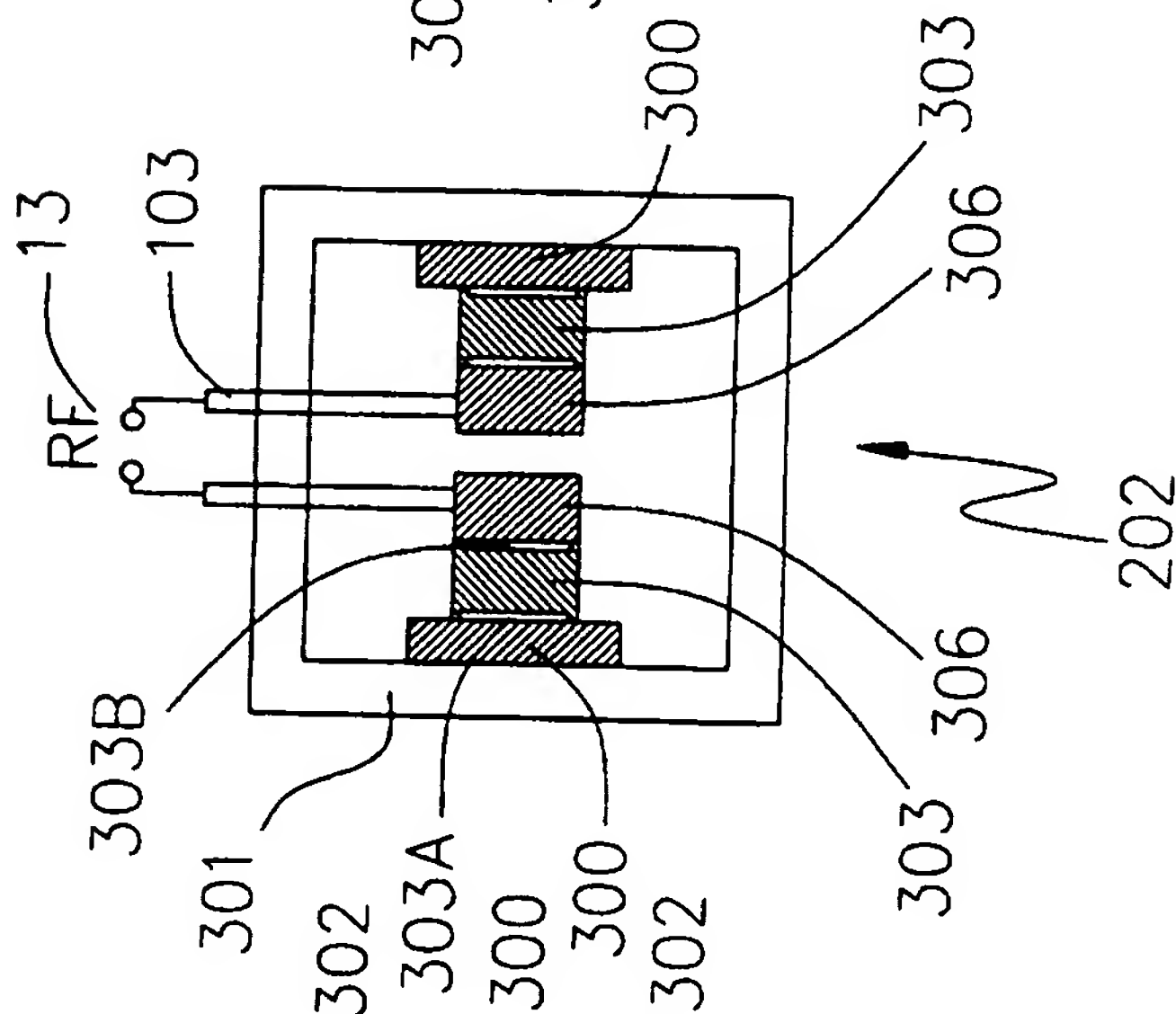
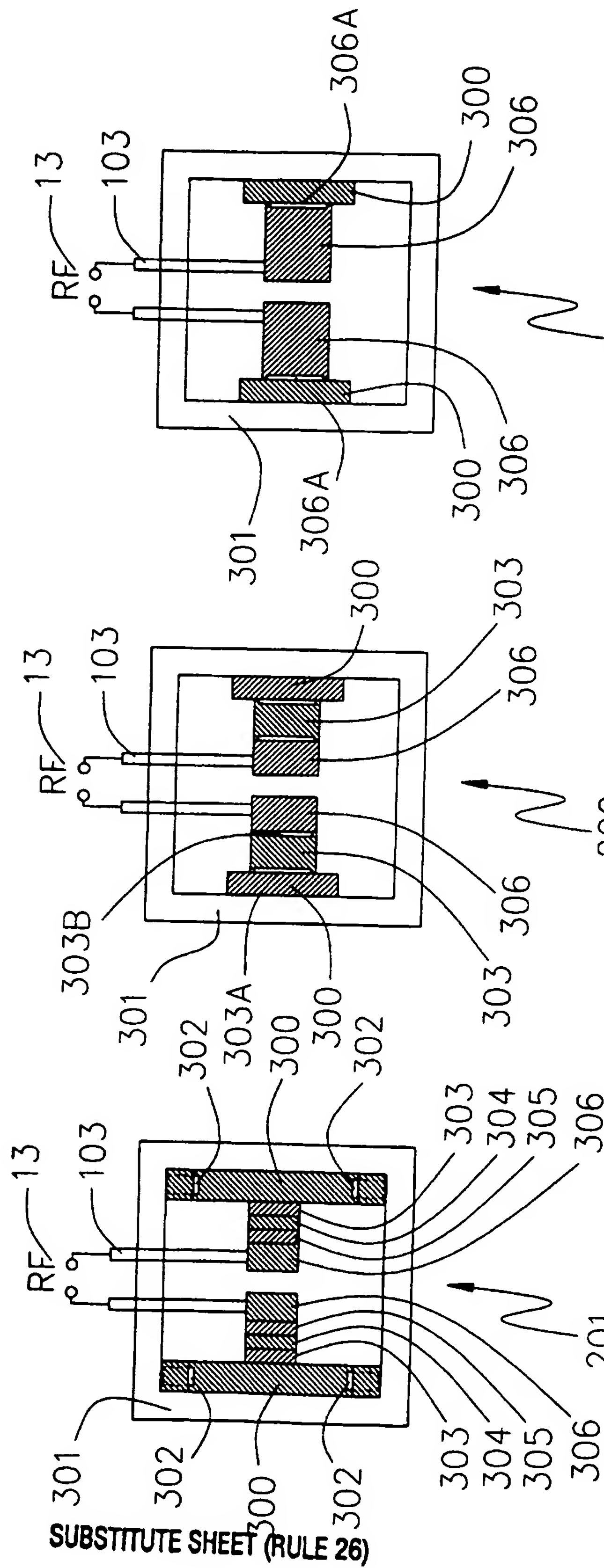
FIG 6











# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/15681

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01S 3/097, 3/04

US CL :372/83, 35, 36

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 372/83, 82, 87, 34, 35, 36

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,151,916 (IEHISA et al) 29 September 1992, see the entire document.	1-23
A	US 4,953,176 (EKSTRAND) 28 August 1990, See the entire document.	26-28
A	US 4,852,109 (KUCCHAR) 25 July 1989, See the entire document.	29

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	A*	document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

14 JANUARY 1997

Date of mailing of the international search report

04 FEB 1997

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 308-7724

Authorized officer

ROBERT E. WISE

Telephone No. (703) 308-4880

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/15681

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☒ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/15681

### BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees have been paid.

Group I, claim(s) 1-23, drawn to minimum electrode spacing in a gas laser, classified in class 372, subclass 83.

Group II, claim(s) 24 and 25, drawn to support members between electrodes of a gas laser, classified in class 372, subclass 83.

Group III, claim(s) 26-28, drawn to heat sinks for a gas laser, classified in class 372, subclass 36.

Group IV, claim 29, drawn to a liquid cooled gas laser, classified in class 372, subclass 35.

and it considers that the International Application does not comply with the requirements of unity of invention (Rules 13.1, 13.2 and 13.3) for the reasons indicated below:

The inventions listed as Groups I-IV do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: each of the four groups of claims is an independent and distinct invention that is unrelated to any other group. Each group of claims recites elements that are not present in other groups, and these unique elements may be a basis for separate patentability of that group of claims.

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